PB PURITAN BENNETT

7200® ventilatory system series

Ventilator, Options, and Accessories

Operator's Manual

Part Number 22300 A
September 1990

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List of Effective Pages

The list of effective pages represents manual P/N 22300, revision A.

Effective Pages	Revision	Effective Pages	Revision
i to xii	A	5-1 to 5-31	A
1-1 to 1-10	A	6-1 to 6-9	A
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3-1 to 3-37	A	Index 1 to 15	A
4-1 to 4-24	A		
Total number of pages in this manual: 190			

Definition of Statements

Statements in this manual preceded by the following words are of special significance.

WARNING – *Means there is a possibility of injury to yourself or others.*

CAUTION - Means there is a possibility of damage to the instrument or other property.

NOTE - Indicates points of particular interest or emphasis that make for more efficient and convenient operation of the equipment.

Warranty

The 7200 Series Ventilator is warranted against defects in material and workmanship in accordance with Puritan-Bennett Medical Equipment Warranty (Form AA-256). Be sure to maintain a record of the maintenance, otherwise the warranty will be voided. (A maintenance record is provided at the end of Chapter 4.)

Preface

This manual is intended to provide information necessary to operate the Puritan-Bennett 7200 Series Ventilator, model 7200ae, which is part of the 7200 Series Ventilatory System. Two keyboard configurations for the ventilator are available; these are described in the manual as the Enhanced and Basic keyboards.

In most cases, messages are described as they look in the message window on the keyboard display panel. Corresponding messages appear on the 7202 Display, if one is installed; these messages are not detailed in this manual.

The manual consists of the following components:

- Chapter 1 provides general information on the ventilator, including specifications and a summary of the ventilator features.
- Chapter 2 is a theory of operation, providing specific information on the function and the design of the ventilator's pneumatic system and microprocessor electronics.
- Chapter 3 explains routine ventilator use. This ranges from pre-operational testing and inspection, selection of ventilator settings and alarms, correction of operator errors, and monitoring of patient and ventilator condition.
- Chapter 4 describes daily and periodic care of the ventilator, covering cleaning and sterilization, and minor maintenance.
- Chapter 5 describes ventilator self-tests in detail.
- Chapter 6 provides procedures for installation of the common accessories and external components of the ventilator.
- The Glossary defines the terms essential in reading this manual and understanding ventilator function.
- Index

It is recommended that the user read this manual thoroughly before operating the equipment. For additional information concerning the 7200 Series Ventilator, see the *7200 Series Ventilator Service Manual* (P/N 4-031052-00) or operator's manuals for any accessory equipment used with the ventilator.

WARNING – *Patients on life-support equipment should be visually monitored by competent medical personnel, since lift-threatening circumstances may arise that may not activate alarms. The operator should heed all appropriate alarms and follow the instructions and warnings in this operator's manual. It is imperative to check life-support equipment for proper operation before use.*

NOTE - In this manual, special brackets are used to set off words in special context. Square brackets ([ ]) signify messages or prompts that appear in the message window on the keyboard display panel. Angle brackets (< >) signify the titles of keys on the keyboard display panel. For example, [APNEA VENTILATION] represents what is shown in the message window when the ventilator is in that emergency mode. The phrase <TIDAL VOLUME> represents the key pressed to set tidal volume. General references to apnea ventilation, tidal volume, and other messages and key titles are printed without the special brackets.

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General Description

This manual describes a microprocessor ventilator in the 7200 Series: the Model 7200ae Ventilator. The 7200ae Ventilator combines improved microprocessor technology with an advanced pneumatic system to achieve reliable and accurate gas delivery and patient monitoring.

An integral design feature is the keyboard display panel, which is available in two versions, the Enhanced (Figure 1-1) and the Basic (Figure 1-2). Both are divided into three sections:

The PATIENT DATA section provides information on breath types, pressures, volumes, rates and ratios.

The VENTILATOR SETTINGS section is used by the operator to select ventilator settings. A two- or three-step entry sequence minimizes accidental or unintentional ventilator changes.

The VENTILATOR STATUS section reports the operating condition and the alarm status.

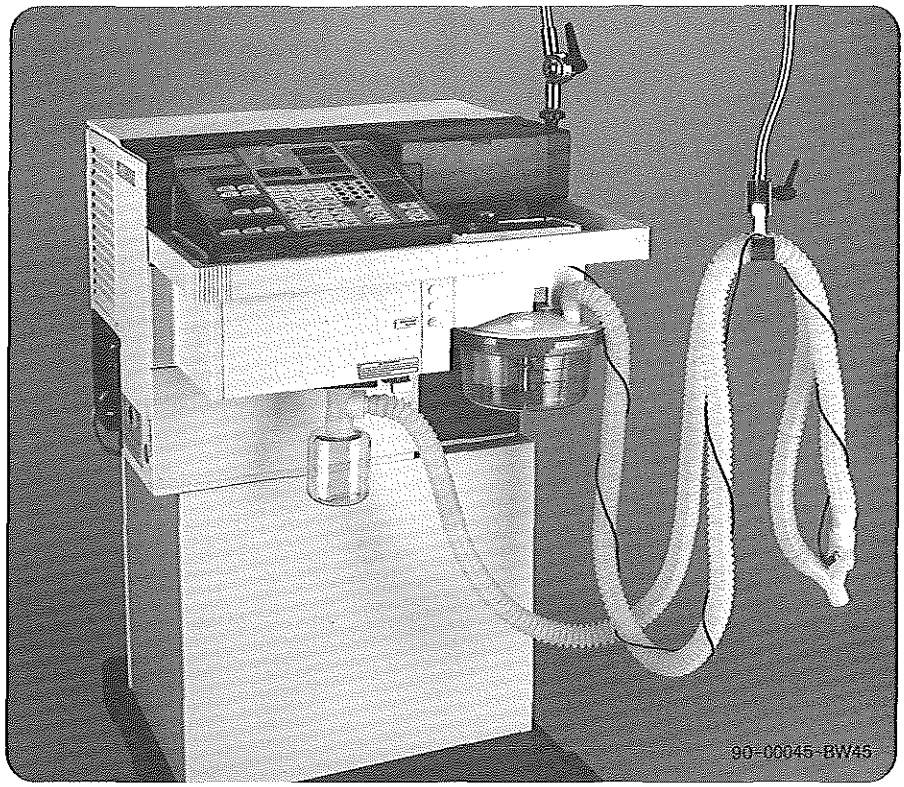


Figure 1-1. 7200ae Ventilator (with Enhanced keyboard)

Applications and General Precautions

The 7200ae Ventilator enables a respiratory care practitioner to provide a patient with ventilatory assistance. It can mix air and oxygen and, when equipped with a humidifier, warm and humidify the mixed gas. It provides a breath of predetermined tidal volume, peak inspiratory flow, waveform, and oxygen composition (a mandatory breath) and can allow a patient to inspire gas having a predetermined oxygen composition from a demand system (a spontaneous breath). Depending on the options installed in the ventilator, the breathing characteristics of the ventilator can be further modified.

The 7200ae Ventilator provides respiratory support for a wide range of patients from pediatric to adult, and for a wide range of clinical conditions.

U.S. federal law restricts this device to the sale by or on the order of a physician.

WARNING – *No amount of microprocessor control and automatic monitoring in the 7200ae Ventilator can eliminate the need for clinical surveillance.*

WARNING – *The 7200ae Ventilator is not designed to be used, nor should it be used, on neonates or infants. The 7200ae Ventilator is not designed for use, nor should it be used, with pediatric patient service circuits.*

WARNING – *To prevent explosion hazard, do not use the ventilator in the presence of flammable anesthetics. The 7200ae Ventilator is not designed for use in procedures involving anesthesia. To prevent fire hazard, keep lighted matches, cigarettes, and other sources of ignition out of the room in which the ventilator is located. Textiles, oils, and other combustibles are easily ignited and burn with great intensity in air enriched with oxygen.*

The following symbols appear on the ventilator:

Symbol	Meaning
	Ventilator meets criteria for Type B medical electrical equipment, defined by the International Electrotechnical Commission (IEC).
	Ventilator meets IEC drip-proof criteria.
	User should consult accompanying documents.
O	Main power off.
I	Main power on.

Features and Specifications

The 7200ae Ventilator is configured either as a stand-alone module or *mounted on a pedestal. The pedestal is available with or without an integral motor/compressor. The compressor can supply the primary air source or act as back-up. Figures 1-1 and 1-2 both show a pedestal installed.*

The 7200ae Ventilator makes extensive use of microprocessor electronics. The microprocessor and its associated electronic circuits control the ventilator and provide for extensive monitoring of patient and ventilator performance. For example, in the pneumatic system, the microprocessor controls the proportional solenoid valves, which mix and shape the flow of inspired air and oxygen. The microprocessor also monitors delivered flow and converts it to a volume measurement at body temperature and pressure and 100% saturation (BTPS).

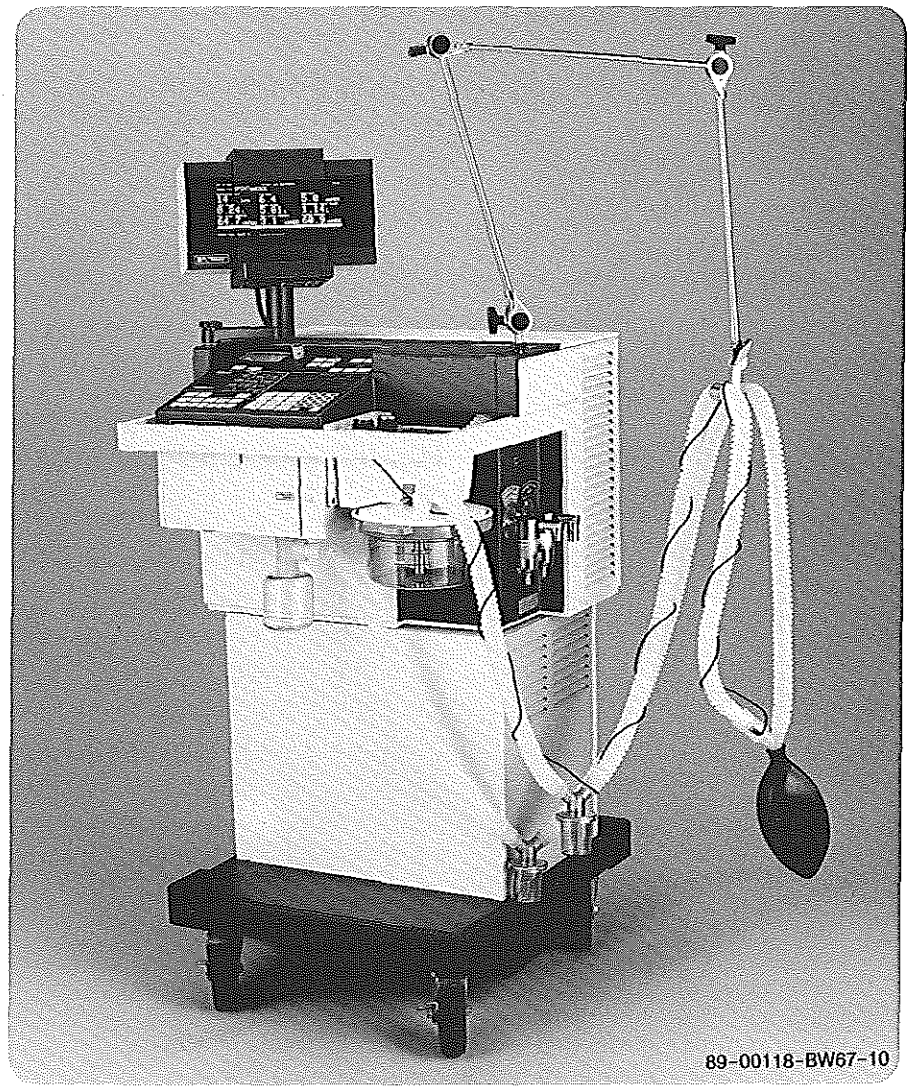


Figure 1-2. 7200ae Ventilator (with Basic keyboard)

The focus of ventilator operation is the keyboard display panel. A membrane touch-pad is used to specify and define ventilatory patterns that meet the specific needs of the patient. Prompts that request operator actions, and messages pertaining to the keyboard, alarm states, and ventilator readiness, appear in the message window.

Replacement of knobs and dials with a keypad and multiple-step entry minimize accidental or unintentional changes in ventilator settings and allow greater precision of ventilator settings. Because the keyboard display panel is a single membrane, the risk of accidental leakage of liquids into the ventilator is lessened.

The 7200ae Ventilator continuously displays breath type, instantaneous airway pressure or exhaled volume, as well as digital readouts of patient and ventilator performance. In addition, the ventilator is equipped with connections for remote alarm activation and/or analog recording of flow and pressure.

Microprocessor electronics make possible the simultaneous integration of information from multiple sensors to warn of many potential problems and to aid in diagnosing abnormal operating conditions. Rather than one general alarm, the 7200ae Ventilator has a hierarchy of alarms that give specific information about operating conditions.

Internal batteries provide sufficient power to keep both the audible alarm and a special section of microprocessor memory functioning for at least one hour when main power to the ventilator has been interrupted. The battery power allows the ventilator to store the last operator-selected settings, even after the ventilator is turned off.

NOTE – During storage or other prolonged periods when the ventilator is not connected to external power, the internal batteries sustain memory for a minimum of 200 days.

Microprocessor electronics execute a Power-On Self-Test (POST), whenever the ventilator is turned on, to verify that it is functioning properly. This start-up test is quick and requires no action by the practitioner. After passing POST, microprocessor electronics continue to monitor the ventilator. If problems are detected, an appropriate emergency mode of ventilation automatically initiates.

Because of the pneumatic system's minimal internal volume and the simplicity of breath-by-breath mixing, changing from one oxygen setting to another is complete within a few breaths (dependent mainly on the volume of the patient service circuit and humidifier).

Both the inspiratory and expiratory limbs of the patient service circuit are isolated from the rest of the ventilator by the main flow and exhalation bacteria filters. Such isolation prevents contamination of the patient by the ventilator and contamination of the pneumatic system, the exhalation flow sensor, or the room air by the patient.

Table 1-1. Technical Data and Specifications

Physical Characteristics	
Dimensions:	
Ventilator Module	Height: 41.9 cm (16.5 in) Width: 55.9 cm (22.0 in) Depth: 56.5 cm (22.5 in)
Ventilator Module with Compressor Pedestal	Height: 102 cm (40.0 in) Width: 55.9 cm (22.0 in) Depth: 64.8 cm (25.5 in)
Weight (approximate):	
Ventilator Module	65 kg (145 lb)
Ventilator Module with Pedestal	109 kg (243 lb)
Ventilator Module with Compressor Pedestal	128 kg (285 lb)
Pedestal	44 kg (98 lb)
Compressor Pedestal	63 kg (140 lb)
Shipping Weight (approximate):	
Ventilator Module	91 kg (202 lb)
Ventilator Module with Pedestal	128 kg (282 lb)
Ventilator Module with Compressor Pedestal	149 kg (328 lb)
Pedestal	69 kg (151 lb)
Compressor Pedestal	92 kg (202 lb)

Environmental Requirements	
Maximum Altitude:	
Operating	3,048 m (10,000 ft)
Storage/Shipping	15,240 m (50,000 ft)
Environmental Temperature:	
Operating	16 to 41°C (60 to 105°F)
Storage/Shipping	-34 to 71°C (-30 to 160°F)
Relative Humidity:	
Operating	0 to 90% noncondensing
Storage/Shipping	0 to 100% noncondensing

Table 1-1. Technical Data and Specifications (continued)

Environmental Requirements (continued)

Clearances for Air Circulation:	Minimum of 15 cm (6.0 in) on all vertical sides
Storage Requirements:	
Less than 200 days	None
More than 200 days	Replace batteries before returning to use

Pneumatic Specifications

Source Pressure:	
Oxygen (DISS 9/16–18), medical grade, dry	241 to 689 kPa (35 to 100 psig)
Air (DISS 3/4–16), medical grade, dry	241 to 689 kPa (35 to 100 psig)
Source Flow:	
Air and oxygen	180 ± 10% Lpm, minimum at 35 psig
Vent Port Leakage:	
Air and oxygen regulators	Approximately 2.0 Lpm each (regardless of incoming pressure)

Electrical Specifications

Model:	Voltage (AC)	Amperage* (rms)	Frequency (Hz)	Power Consumption* (W)
Ventilator Module	115 ± 10%	3.8	60 ± 5%	437
	100 ± 10%	3.0	60 ± 5%	300
	100 ± 10%	3.4	50 ± 3%	340
	220 ± 10%	1.7	50 ± 3%	374
	240 ± 10%	1.7	50 ± 3%	408
Compressor Pedestal	115 ± 10%	4.7	60 ± 5%	978
	100 ± 10%	6.8	60 ± 5%	980
	100 ± 10%	6.4	50 ± 3%	980
	220 ± 10%	2.6	50 ± 3%	946
	240 ± 10%	2.4	50 ± 3%	984

*Amperage and power consumption assume the connection of a Cascade II Humidifier

Humidifier Outlet Power Rating:	230 watts
Leakage Current: Ventilator Module with Compressor Pedestal	Less than 100 μA at 115 V/100 V Less than 500 μA at 220/240 V
Power Cord	125 (240) VAC hospital grade, UL and CSA approved, 3.05 m (10.0 ft) for 115 V/100 V 1500 VAC, VDE and CSA approved, detachable, 2.5 m (8.2 ft) for 220/240 V
Internal Batteries (2)	Lead acid, 2.1 VDC typical, General Electric, sealed X-cell, 5 ampere-hour rating

Table 1-1. Technical Data and Specifications (continued)

Electrical Specifications (continued)

Start-Up Current:	
Ventilator, 115 V, with compressor	20 amperes
Heat Dissipation:	
Ventilator Module	Approximately 510 BTU/hour
Ventilator with Compressor	Approximately 2400 BTU/hour (where 1 kW = 3412 BTU/hour)

Ventilator Data

Gas Inlet Protection:	
Filtering capability, air and oxygen	Particle size 0.3 μ with 99.8% efficiency. Water filter will not remove water vapor from gas. Use dry gas only.
Operator-Selected Parameters:	
Tidal Volume	0.10 to 2.50 liters
Respiratory Rate	0.5 to 70 bpm
Peak Inspiratory Flow, maximum	10 to 120 Lpm, operator-selected; 180 Lpm during spontaneous breathing
Sensitivity, inspiratory	0.5 to 20 cmH_2O below PEEP
O_2%	21 to 100%
Plateau	0.0 to 2.0 seconds
PEEP/CPAP Pressure	0 to 45 cmH_2O
Operator-Selected Alarm Thresholds:	
High Pressure Limit	10 to 120 cmH_2O
Low Inspiratory Pressure	3 to 99 cmH_2O
Low PEEP/CPAP Pressure	0 to 45 cmH_2O
Low Exhaled Tidal Volume	0.00 to 2.50 liters
Low Exhaled Minute Volume	0.00 to 60.0 liters
High Respiratory Rate	0 to 70 bpm
Operator-Selected Modes and Special Functions:	
CMV, SIMV, CPAP	Selects modes of ventilation
+ +	Accesses <++> key functions
Operator-Selected Flow Waveforms:	
Square, Descending ramp, Sine	Selects waveform for mandatory breaths

Table 1-1. Technical Data and Specifications (continued)

Ventilator Data (continued)

Operator-Selected Functions:

Manual Inspiration	Delivers one mandatory breath
Manual Sigh	Delivers one mandatory sigh tidal volume
Automatic Sigh	Allows operator to select values for the four sigh parameters; turns function on and off
100% O_2 Suction	Switches O_2% to 100% for two minutes or until turned off
Nebulizer	Activates nebulizer for 30 minutes maximum or until turned off

Operator-Selected Alarm Control Keys:

Alarm Silence	Silences audible alarm and remote nurse's call for two minutes
Alarm Reset	Resets ventilator to pre-alarm state

Alarms:

High Pressure Limit	Airway pressure exceeds alarm threshold
Low Inspiratory Pressure	Peak airway pressure during delivery of a mandatory breath is below alarm threshold
Low PEEP/CPAP Pressure	Airway pressure is below alarm threshold
Low Exhaled Tidal Volume	Tidal volume is below alarm threshold
Low Exhaled Minute Volume	Minute volume is below alarm threshold
High Respiratory Rate	Respiratory rate exceeds alarm threshold
I:E	Illuminates if value greater than 1:1 (e.g. 1:0.5)
Apnea	Illuminates if no breath is detected during the apnea interval
Low Pressure O_2 Inlet	Supply O_2 pressure is below 35 psig if O_2% is not 21%
Low Pressure Air Inlet	Supply air pressure is below 35 psig for wall gas and 7.4 psig for the compressor
Exhalation Valve Leak	Gas flow through the exhalation flow sensor during breath delivery is 50 ml or 10% of delivered volume, whichever is greater
Low Battery	Illuminates if less than one hour reserve power for audible alarm
Power Disconnect Alarm	AC power to the ventilator is interrupted; only the audible alarm sounds

Alarm Summary Display:

VENTILATOR INOPERATIVE (red) VENTILATOR ALARM (red) CAUTION (yellow) BACK UP VENTILATOR (red) SAFETY VALVE OPEN (red) NORMAL (blue or green)	Illuminates to indicate ventilator status

Table 1-1. Technical Data and Specifications (continued)

Ventilator Data (continued)

Operator-Selected or Monitored Parameters:

Airway Pressure (analog meter)	Continuous display, breath-by-breath
Exhaled Volume (analog meter)	Continuous display, breath-by-breath *(available only on Basic keyboards)*

Breath-Type Indicator Lights (automatic):

Assist, Spontaneous, Sigh, Plateau	*Illuminates during appropriate breath or breath cycle*

Patient Data Displays:

Mean Airway Pressure, Peak Airway Pressure, PEEP/CPAP Pressure, Plateau Pressure	In cmH_2O: three-digit display (maximum of two digits to the right of the decimal
Respiratory Rate	In breaths per minute: three-digit display (maximum of one digit to the *right of the decimal)*
I:E Ratio	Two-digit display (maximum of one digit to the right of the decimal)
Tidal Volume, Minute Volume, Spontaneous Minute Volume	In liters: three-digit display (two digits to the right of the decimal)

Emergency Modes of Operation:

Apnea Ventilation, *Disconnect Ventilation*	Parameters are selected by the operator
Back up Ventilator	Temporary ventilatory support with factory-preset parameters
Safety Valve Open	Patient breathes room air unassisted by ventilator

Self-Diagnostics:

Power-On Self-Test (POST)	Automatic after power on (approximately 5 second duration)
Quick Extended Self-Test (QUEST)	Operator-selected (1-1/2 minute duration)
Total Extended Self-Testy (TEST)	Operator-selected (3 to 5 minute duration)
Ongoing Checks	Automatic, continuous during ventilator operation
I:E Ratio Check	Automatic, with parameter changes
Lamp Test	Operator-selected

Table 1-1. Technical Data and Specifications (continued)

Ventilator Data (continued)

Output Signals:

Remote Nurse's Call	For remote indication of alarm
Analog signals for pressure & flow	For display of signals on separate recording device

WARNING *– The nurse's call relay from the output signal connector does not signal loss of power. Patients on life-support equipment should be visually monitored by competent medical personnel, since life-threatening circumstances may arise that might not activate alarms.*

Theory of Operation 2

This chapter generally describes the function of the 7200ae Ventilator. *Sections within this chapter explain the component systems* of the ventilator and their functional interrelationships, basic ventilator operation, calculation of patient data for displays, and safety features.

Overview of Ventilator Systems

Function of the ventilator relies on interaction of the following systems:

- two gas supplies – one providing air and one providing oxygen (a compressor may be ordered as an alternate air source);
- a pneumatic system that mixes the gases, generates flow waveforms, delivers volumes, and measures pressures;
- a patient service system that routes the mixed gases to and from the patient;
- a keyboard display panel used to specify the operation of the pneumatic system, monitor patient and ventilator performance, and signal the operator with alarms when specified problems occur; and
- microprocessor electronics that controls and monitors the pneumatic system, the keyboard display panel, and the utility panel.

The functional relationship of the ventilator's systems, the operator, and the patient is shown in Figure 2-1.

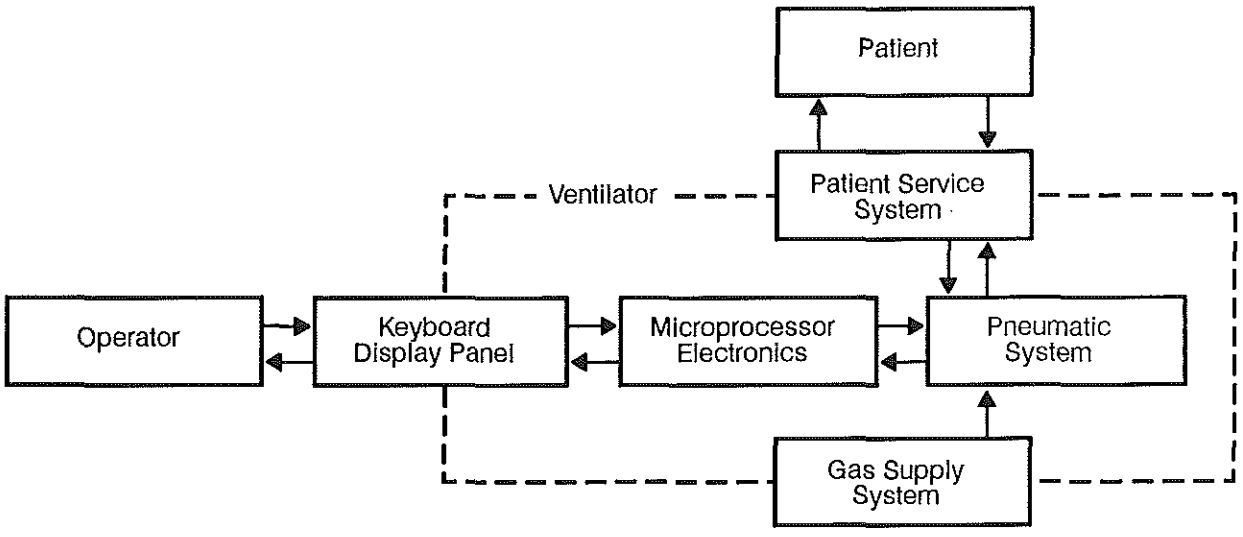


Figure 2-1. Functional Relationship of the Operator, Patient, and Ventilator

Power Requirements

In general, the ventilator's electrical and electronic systems operates with DC power. However, the optional compressor pedestal, the exhalation filter heater, and the humidifier outlet are powered by wall AC current. Internal batteries provide reserve power to memory in the microprocessor electronics.

Gas Supply System

The external portion of the ventilator's gas supply system is illustrated in Figure 2-2.

Both air and oxygen enter the ventilator through filters that remove particulate matter (larger than 0.3 microns) and condensed moisture in aerosol form. (Bulk water must be removed from wall air sources with a separate water trap.)

The optional compressor pedestal enables the ventilator to operate independently of compressed wall air.

The minimum operating pressure for wall-supplied air or oxygen is 35 psig; the maximum is 100 psig. Internal preset regulators reduce internal supply pressure to 10 psig. The optional compressor produces a pressure of approximately 10 psig. An automatic gas-supply switching circuit provides for emergency operation whenever gas supply inlet pressure or compressor pressure falls below a prescribed range (this may be less than the minimum operating pressure). For this switchover to operate effectively, the ventilator must have oxygen and air supplies attached (or for air supply, a compressor must be installed).

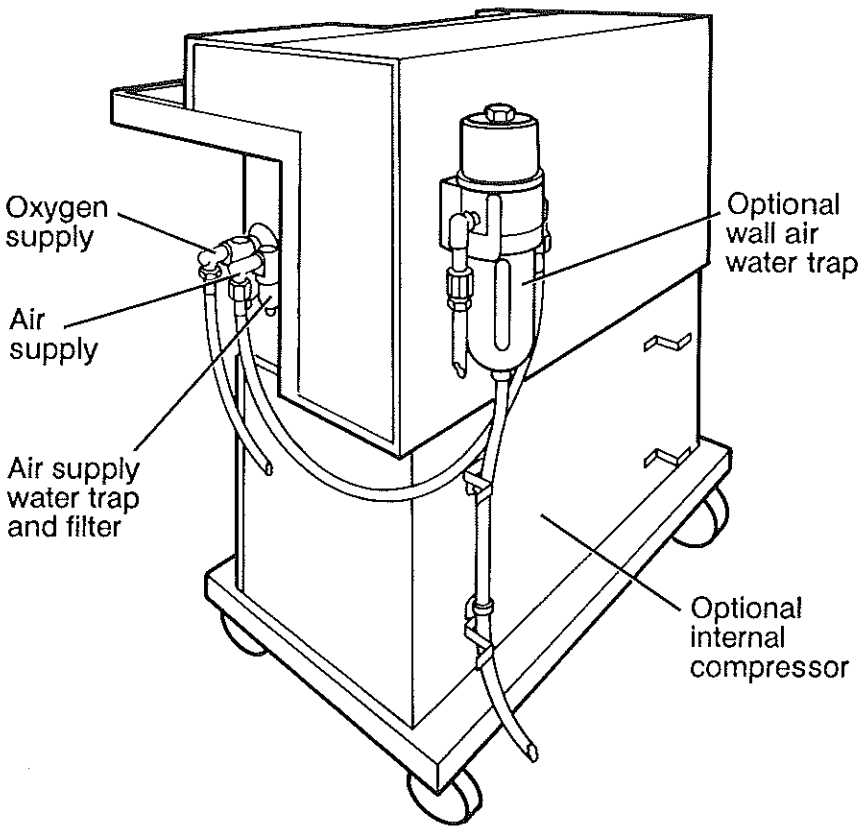


Figure 2-2. External Components of the Gas Supply System

Pneumatic System

The major components of the pneumatic system are illustrated in Figure 2-3.

The system consists of the flow sensors (for inspired air and oxygen, and exhaled flow), the paired proportional solenoid valves, and the ventilator outlet port (this includes a safety valve). In addition, the system contains check valves for preventing retrograde gas flow, a subsystem for providing positive end expiratory pressure (PEEP), and a subsystem for providing flow to the nebulizer.

Microprocessor electronics (described in the following section) controls the solenoid valves, monitors the amount of gas flowing through them, and continually adjusts the flow to ensure that the operator-selected volume, flow rate, waveform, and composition of gas is delivered to the patient.

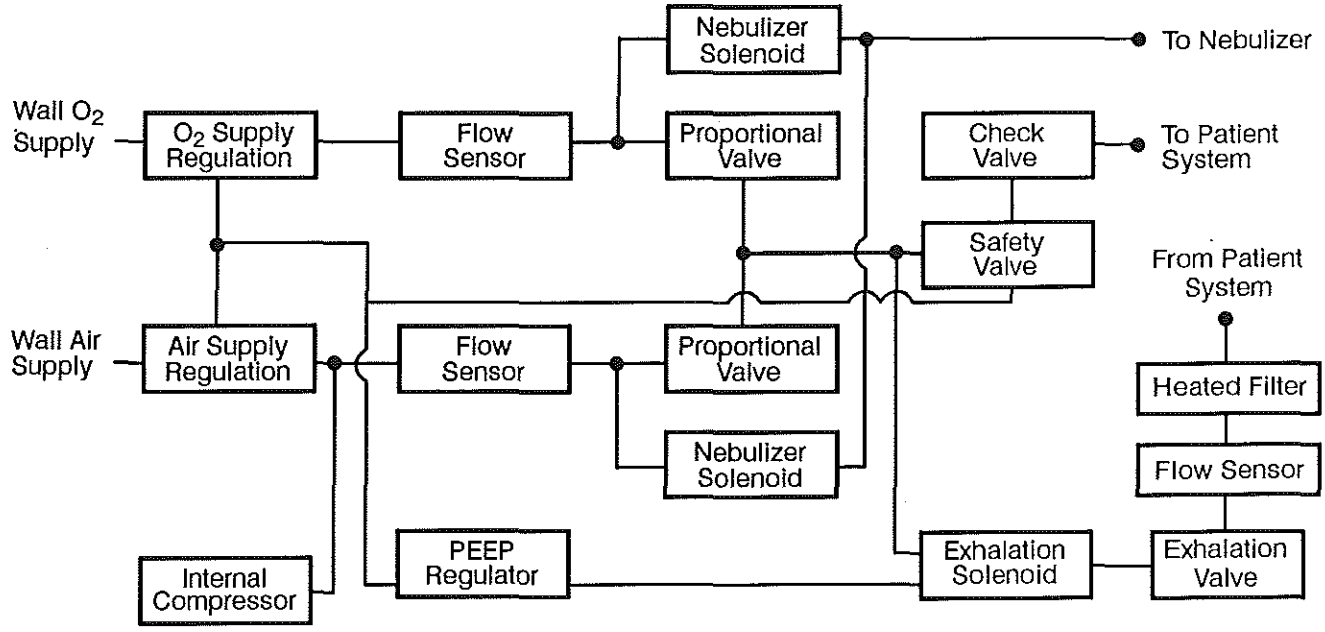


Figure 2-3. Major Components of the Pneumatic System

Microprocessor Electronics

The major components of the ventilator's microprocessor electronics are illustrated in Figure 2-4.

The microprocessor, memory, keyboard control, display control, conversion circuitry, and interface circuitry are contained on printed circuit boards. These boards contain the electronic components necessary to control and monitor ventilator operation.

The microprocessor receives information from the keyboard, utility panel, DC power supply, and memory, as well as from pressure switches and temperature/flow sensors in the pneumatic system. The microprocessor monitors the information from these sources and performs the necessary calculations based on programs stored in memory. As a result of these calculations, status information and control signals are sent to the pneumatic system and to the displays.

The signals sent to the pneumatic system control gas flow and pressure delivered to the patient. Information sent to the displays indicates ventilator status and patient data. Some options have additional circuitry; the microprocessor receives and coordinates the functions of those options.

The memory contains several types of information required by the microprocessor:

- software programs that control the microprocessor during normal operation
- default values that control the microprocessor during emergency operation
- results of various calculations performed by the microprocessor, and
- last-entered, operator-selected ventilator settings.

The operator-selected ventilator settings portion of the memory is protected by battery power. This battery power allows the ventilator to retain all previously entered ventilator settings when the ventilator is turned off or when there is a power failure. The ventilator retrieves and begins operating with these settings after main power is restored and the Power-On Self–Test (POST) is successfully completed.

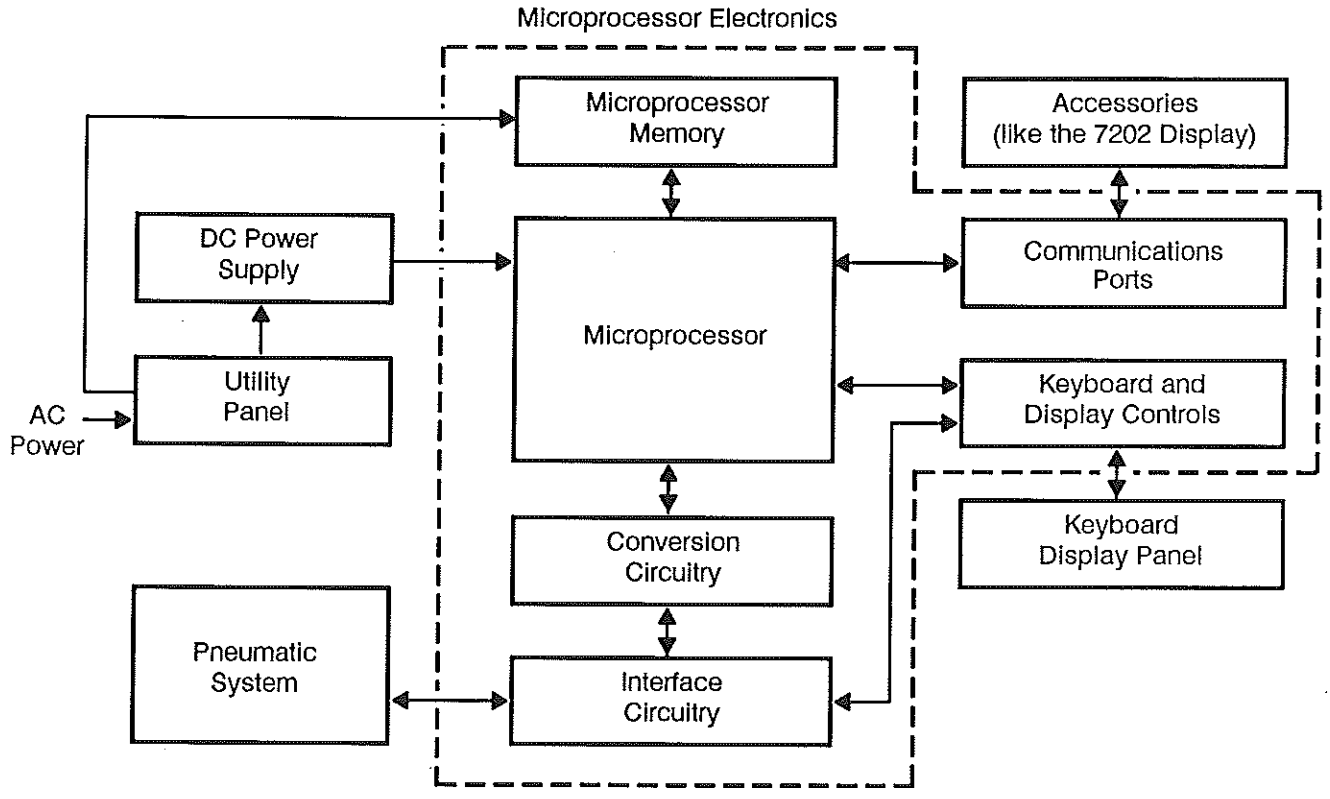


Figure 2-4. Major Components of Ventilator Microprocessor Electronics

Patient Service System

The major components of the patient service system are illustrated in Figure 2-5.

The patient service system consists of the humidifier circuit, for warming and humidifying the inspiratory gas; the patient service circuit, for transporting the gas from the pneumatic system to the patient and back to the ventilator; the nebulizer circuit, for adding medication to the gas; and exhalation flow circuit, for monitoring and calculating the volume of exhaled gas.

The system also contains filters in its inspiratory and expiratory limbs that confine bacterial contamination in the humidifier and patient service circuits; water traps, that minimize the amount of condensate in the patient circuit; a check valve, that prevents retrograde gas flow; and an exhalation valve that seals the system during inspiration and maintains PEEP.

The internal exhalation valve is housed in the exhalation compartment. Because exhalation compartment components are the last elements in the expiratory limb (downstream from the heated exhalation bacteria filter), they do not need to be cleaned and sterilized.

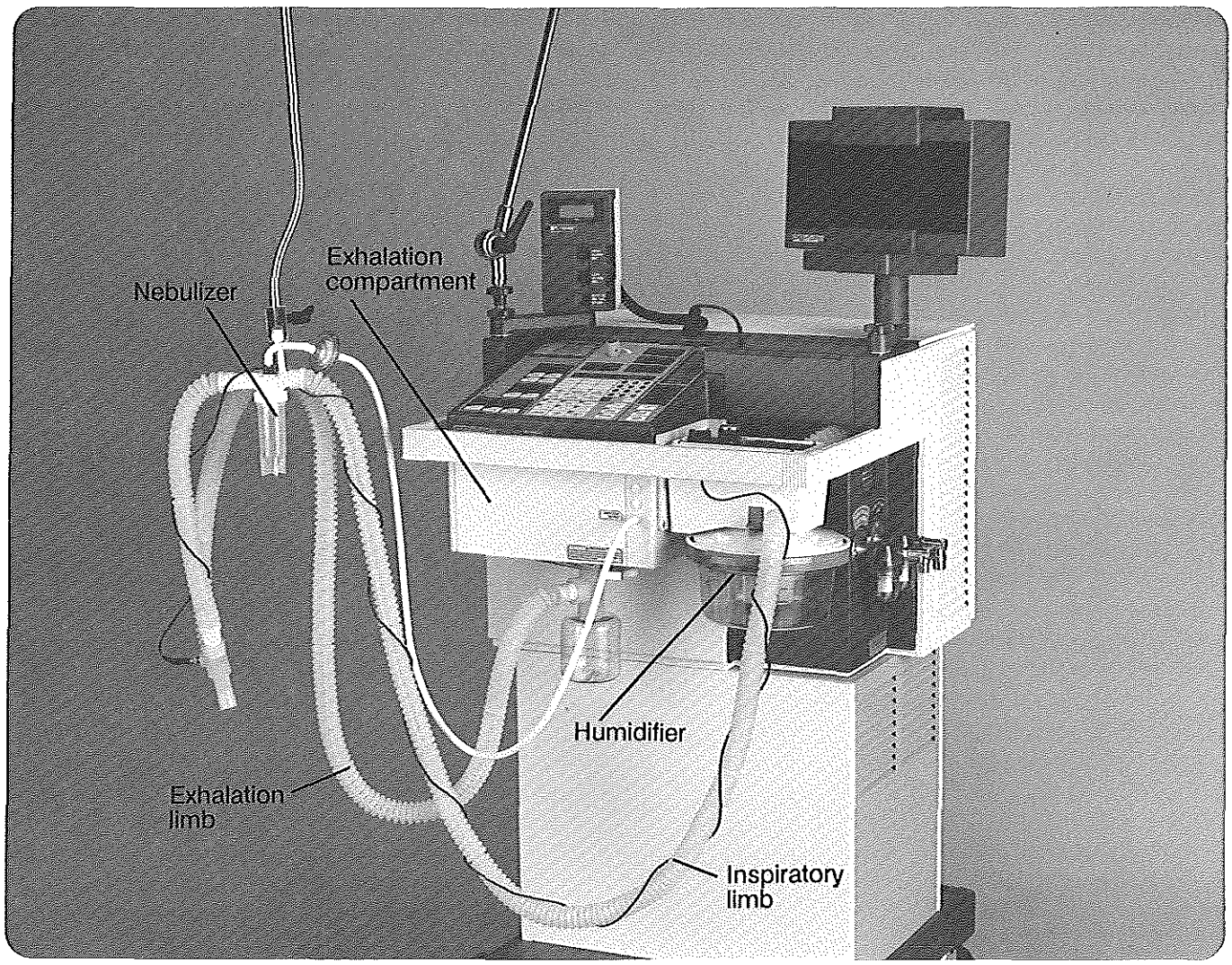


Figure 2-5. Major Components of the Simplified Patient Service System

Keyboard Display Panel

The keyboard display panel consists of the keys and the knob that specify how the ventilator delivers breaths. The panel also contains the displays and indicators that report patient data and ventilator status. The keys, knob, displays, and indicators illustrated in Figure 2-6, are grouped in sections by function: PATIENT DATA, VENTILATOR SETTINGS, and VENTILATOR STATUS.

The PATIENT DATA section displays patient information on pressures, volumes, rates, I:E ratios, and breath types.

Select ventilator settings with the keys in the VENTILATOR SETTINGS section. As ventilator settings and alarm thresholds are selected, the values are shown in the message window. Tidal volume, respiratory rate, peak inspiratory flow, and oxygen composition percentage for delivered breaths appear continuously in the section's digital displays. You may also initiate special functions with the <MANUAL INSPIRATION>, <MANUAL SIGH>, <AUTOMATIC SIGH>, <NEBULIZER> and <100% O_2 SUCTION> keys. The <++> key allows you to access special functions and options.

The 12 specific alarm indicators and six general status displays in the VENTILATOR STATUS section notify you of alarm conditions and emergency ventilatory modes. The alarm summary display signals the operator to ventilator operating condition; four red lights identify emergency operating situations. The <ALARM SILENCE>, <ALARM RESET>, and <LAMP TEST> keys are also in this section.

Two types of keyboards are available for the 7200ae Ventilator: the Enhanced and the Basic. The Enhanced is a multi-color keyboard, with the PATIENT DATA section on the left, the VENTILATOR SETTINGS section in the middle, and the VENTILATOR STATUS section on the right. The analog meter continously displays airway pressure.

The Basic keyboard is charcoal gray with colored borders to separate the sections. The PATIENT DATA section is at the top, the VENTILATOR STATUS section is on the left, and the VENTILATOR SETTINGS section is on the lower right. Two keys for the analog meter allow the operator choose between airway pressure and exhaled volume.

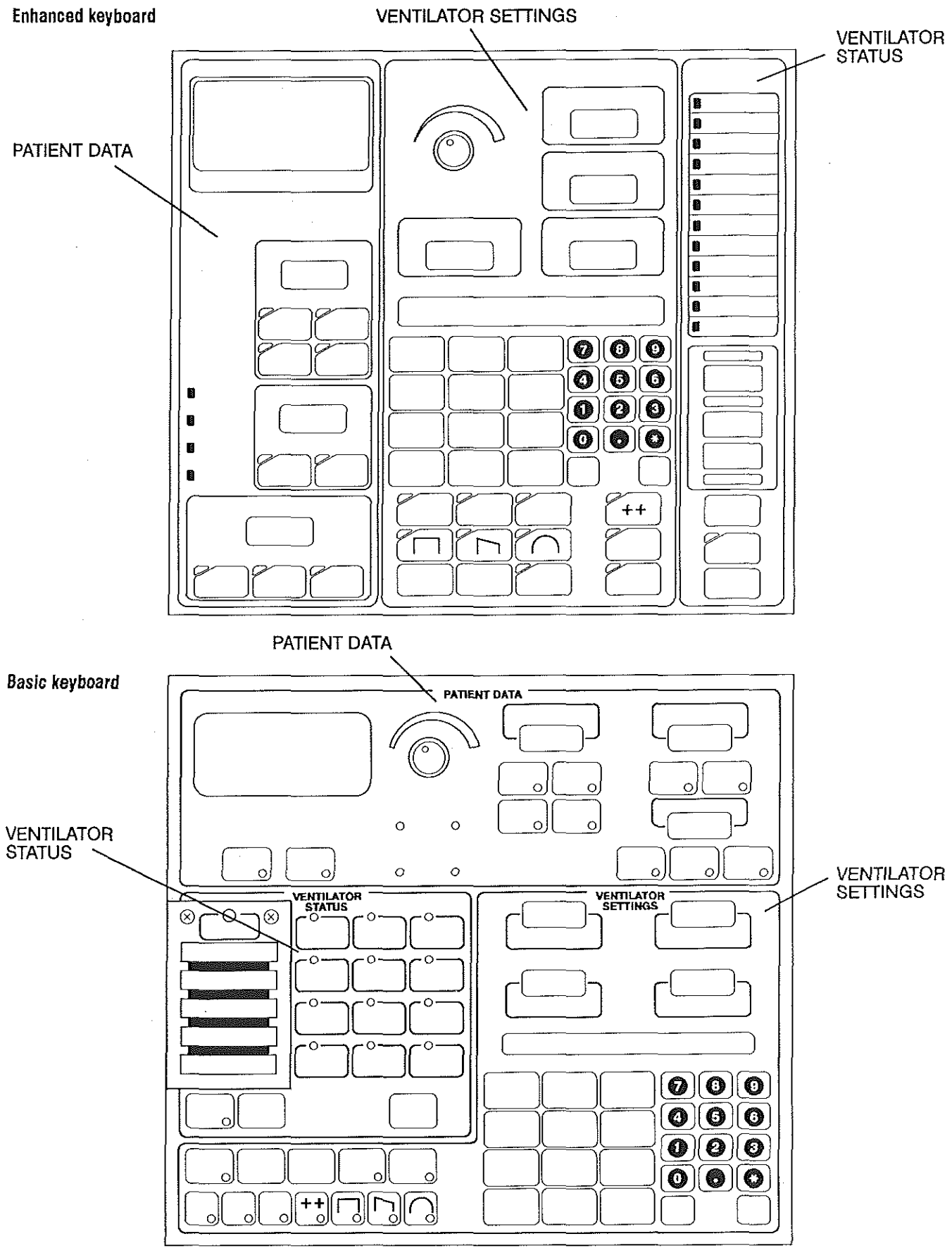


Figure 2-6. Organization of the Keyboard Display Panel

Table 2-1. Function of Ventilator Controls on the Keyboard Display Panel

NOTE – Certain keys have special functions when used during Extended Self-Test (EST). See Chapter 5 for details.

Key, Indicator, or Display	Function
Ventilator Settings Section	
PEEP/CPAP (control knob)	Allows for setting the Positive End Expiratory Pressure (PEEP).
TIDAL VOLUME	Allows for reviewing and specifying delivered tidal volume for mandatory breaths, corrected for BTPS and compliance volume.
RESPIRATORY RATE	Allows for reviewing and specifying respiratory rate for ventilator-initiated mandatory breaths (sets the CMV and SIMV respiratory rates).
PEAK INSPIRATORY FLOW	Allows for reviewing and specifying peak inspiratory flow for mandatory breaths.
SENSITIVITY	Allows for reviewing and specifying the amount of airway pressure (measured in the patient service system) by which PEEP must be reduced by the patient in order to trigger a patient-initiated mandatory or spontaneous breath. SENSITIVITY is defined as a negative pressure, but is entered and displayed without a negative sign.
O_2%	Allows for reviewing and specifying the percentage of oxygen gas of which all breaths are composed.
PLATEAU	Allows for reviewing and specifying the duration of the inspiratory pause following the delivery of all mandatory breaths.
HIGH PRESSURE LIMIT	Allows for reviewing and specifying the airway pressure limit for the HIGH PRESSURE LIMIT alarm during mandatory and spontaneous breaths. If airway pressure is greater than the limit value, the HIGH PRESSURE LIMIT alarm triggers.
LOW INSPIRATION PRESSURE	Allows for reviewing and specifying the airway pressure limit for the LOW INSPIRATORY PRESSURE alarm during a mandatory breath. If airway pressure is less than the limit value, the LOW INSPIRATORY PRESSURE alarm triggers.
LOW PEEP/CPAP PRESSURE	Allows for reviewing and specifying the airway pressure limit for the LOW PEEP/CPAP PRESSURE alarm. If airway pressure is less than the limit value, the LOW PEEP/CPAP PRESSURE alarm triggers.
LOW EXHALED TIDAL VOL	Allows for reviewing and specifying the limit for the LOW EXHALED TIDAL VOL alarm. If the exhaled tidal volume, averaged over four breaths, is less than the limit value, the LOW EXHALED TIDAL VOL alarm triggers.
LOW EXHALED MINUTE VOL	Allows for reviewing and specifying the limit for the LOW EXHALED MINUTE VOL alarm. If the total exhaled minute volume is less than the limit value, the LOW EXHALED MINUTE VOL alarm triggers.
HIGH RESPIRATORY RATE	Allows for reviewing and specifying the limit for the HIGH RESPIRATORY RATE alarm. If the respiratory rate is greater than the limit value, the HIGH RESPIRATORY RATE alarm triggers.
Numeric key pad (0 through 9)	Allows for entering specific values for parameters, alarm limits, and <++> key functions.
Decimal point	Allows for entering decimal values for parameters, alarm limits, and <++> key functions.
*	Allows for stepping through <++> key function parameters in reverse direction; also used in EST and automatic sigh procedures.
ENTER	Causes the ventilator to perform operator selections. Also allows for stepping forward through <++> key function and automatic sigh parameters.

Table 2-1. Function of Ventilator Controls on the Keyboard Display Panel (continued)

Key, Indicator, or Display	Function
Ventilator Settings Section (continued)	
CLEAR	Erases the displayed value of a parameter, alarm limit, or <++> key function from the message window. Although pressing the <CLEAR> key causes window values to be erased, ventilator operating settings are not erased.
CMV	Selects the Continuous Mandatory Ventilation mode.
SIMV	Selects the Synchronous Intermittent Mandatory Ventilation mode.
CPAP	Selects the Continuous Positive Airway Pressure mode.
Square wave	Selects square waveform for mandatory breaths.
Descending ramp	Selects descending ramp waveform for mandatory breaths.
Sine wave	Selects sine waveform for mandatory breaths.
MANUAL INSPIRATION	Delivers one operator-initiated mandatory breath.
MANUAL SIGH	Delivers one operator-selected sigh breath (if sigh parameters have been set).
AUTOMATIC SIGH	Delivers sigh breaths as set by the operator. Press key again to turn off function.
++	Accesses <++> key functions.
100% O_2 SUCTION	Switches ventilator to 100% O_2 for 2 minutes (if O_2 is available). Press key again to cancel.
NEBULIZER	Turns on or off the nebulizer circuit. Automatically cancels after 30 minutes; temporarily suspended in emergency modes. Press key again to cancel.
TIDAL VOL liters display	Displays the digital value of the current ventilator setting for TIDAL VOLUME for non-sigh mandatory breaths; flashes when current values differ from operator-entered parameters.
SET RATE bpm display	Displays the digital values for current ventilator setting for RESPIRATORY RATE; flashes when current values differ from operator-entered parameters.
PEAK FLOW lpm display	Displays the digital value of the current ventilator setting for PEAK INSPIRATORY FLOW; flashes when current values differ from operator-entered parameters.
O_2% display	Displays the digital value of the current ventilator setting for percent of oxygen in the inspiratory gas; flashes when current values differ from operator-entered parameters.
Message window	Displays prompts and values for parameters, alarm thresholds, and <++> key functions. Also displays error messages, error codes, and alarms.
Ventilator Status Section	
LAMP TEST	Initiates a test that checks all lamps, displays, and meters, on the keyboard display panel, the audible alarm, and the nurse's call; cancels alarm silence.
ALARM SILENCE	Suspends the audible alarm for 2 minutes and cancels display of self-test error messages.
ALARM RESET	Clears all alarm indicators and initiates a battery test; cancels alarm silence; during EST, provides the [OVERRIDE -- ENTER] prompt after and EST COMPLETE or EST FAIL state.

Table 2-1. Function of Ventilator Controls on the Keyboard Display Panel (continued)

Key, Indicator, or Display	Function
Alarm Summary Display	
VENTILATOR INOPERATIVE	Indicates that the ventilator is nonoperational.
VENTILATOR ALARM	Indicates that an alarm has triggered due to detected violation of an alarm limit. Also indicates detection of apnea or an exhalation valve leak.
CAUTION	Indicates that an alarm triggered previously, but the condition was corrected and the alarm stopped automatically.
BACK UP VENTILATOR	Indicates that the ventilator is operating in the BACK UP VENTILATOR emergency mode.
SAFETY VALVE OPEN	Indicates that the ventilator's safety valve is open and that the patient is breathing room air, unassisted by the ventilator.
NORMAL	Indicates that no alarm or caution states exist (other than the I:E or Low Battery alarm).
Alarm Indicators	
HIGH PRESSURE LIMIT	Indicates that airway pressure is greater than the limit value set for this alarm; when the alarm triggers, the ventilator terminates a mandatory inspiration.
LOW INSPIRATORY PRESSURE	Indicates that mandatory breath peak airway pressure is less than the limit value for this alarm.
LOW PEEP/CPAP PRESSURE	Indicates that airway pressure is less than the limit set for this alarm for a period greater than 1 second, or that 5 liters or more have been delivered during a spontaneous breath.
LOW EXHALED TIDAL VOL	Indicates that the 4-breath running average for tidal volume is less than the limit value set for this alarm.
LOW EXHALED MINUTE VOL	Indicates that the total minute volume calculation is less than the limit value for this alarm; the calculation is based on an 8-breath or 1 minute average.
HIGH RESPIRATORY RATE	Indicates that the 10-breath running average for respiratory rate is greater than the limit value set for this alarm.
I:E	Indicates that the duration of inspiration is 50% or more of the total cycle interval (e.g., a ratio of 1:0.9 triggers the alarm).
APNEA	Indicates that the ventilator did not detect initiation of an exhalation during the apnea interval.
LOW PRESSURE O_2 INLET	Indicates that inlet pressure for the oxygen supply has fallen below a prescribed level while O_2% (or apnea O_2%) is set greater than 21.
LOW PRESSURE AIR INLET	Indicates that wall air inlet pressure has fallen below a prescribed level. Also, if wall pressure is insufficient, indicates that compressor pedestal inlet pressure (if included) has fallen below a prescribed level.
EXHALATION VALVE LEAK	Indicates that more than 10% of the delivered tidal volume or 50 ml (whichever is greater) passed through the exhalation flow sensor during inspiration
LOW BATTERY	Indicates that the voltage of the internal batteries is too low to sustain 1 hour of audible alarm operation.

Table 2-1. Function of Ventilator Controls on the Keyboard Display Panel (continued)

Key, Indicator, or Display	Function
Patient Data Section	
Analog Meter Keys	
AIRWAY PRESSURE cmH_2O	Selects analog meter display of airway pressure (only available on Basic keyboard). (The analog meter on the Enhanced keyboard continuously displays airway pressure.)
EXHALED VOLUME liters	Selects analog meter display of volume passing through the exhalation valve, uncorrected for BTPS or compliance volume (only available on Basic keyboard).
cmH_2O Window Keys	
MEAN AIRWAY PRESSURE	Selects calculated mean airway pressure for display in the cmH_2O (pressure) window.
PEAK AIRWAY PRESSURE	Selects measured peak airway pressure of the last mandatory breath for display in the cmH_2O (pressure) window.
PEEP/CPAP (display)	Selects calculated PEEP/CPAP pressure for display in the cmH_2O (pressure) window.
PLATEAU PRESSURE	Selects measured plateau pressure for display in the cmH_2O (pressure) window; display blanked when plateau equals 0.
RATE/I:E Window Keys	
RATE bpm	Selects measured respiratory rate for display in the RATE/I:E window.
I:E RATIO	Selects measured I:E ratio of the last mandatory breath for display in the RATE/I:E window.
liters Window Keys	
TIDAL VOLUME	Selects measured, BTPS-corrected, tidal volume for display in the liters (volume) window.
MINUTE VOLUME	Selects measured, BTPS-corrected, minute volume for display in the liters (volume) window.
SPONT MINUTE VOLUME	Selects measured, BTPS-corrected, spontaneous minute volume for display in the liters (volume) window; display blanked whenever the ventilator is in CMV (including emergency modes).
Breath-Type Indicators	
ASSIST	Illuminates during the inspiratory phase of a patient-initiated mandatory breath cycle.
SPONTANEOUS	Illuminates during the inspiratory phase of a spontaneous breath cycle
SIGH	Illuminates for a period from the start of inspiration through the end of exhalation for a sigh breath.
PLATEAU	Illuminates during an inspiratory pause.

Table 2-2. Window Messages and Their Meanings

Modes, Waveforms, Other Features **Function**

Mode, waveform, and other messages appear after pressing the corresponding keys.

Message	Meaning and/or Action
100% O_2 ON–ENTER	Prompts the operator to turn on 100% oxygen by pressing <ENTER>
100% O_2 OFF–ENTER	Prompts the operator to turn off 100% oxygen by pressing <ENTER>
AUTO SIGH ON–ENTER	Prompts the operator to turn on automatic sigh by pressing <ENTER> (after sigh parameters are selected)
AUTO SIGH OFF–ENTER	Prompts the operator to turn off automatic sigh by pressing <ENTER>
NEB ON–ENTER	Prompts the operator to turn on nebulizer by pressing <ENTER>
NEB OFF–ENTER	Prompts the operator to turn off nebulizer by pressing <ENTER>
CMV MODE–ENTER	Prompts the operator to select CMV mode by pressing <ENTER>
SIMV MODE–ENTER	Prompts the operator to select SIMV mode by pressing <ENTER>
CPAP MODE–ENTER	Prompts the operator to select CPAP mode by pressing <ENTER>
SQUARE SHAPE–ENTER	Prompts the operator to select square waveform by pressing <ENTER>
RAMP SHAPE–ENTER	Prompts the operator to select descending ramp waveform by pressing <ENTER>
SINE SHAPE–ENTER	Prompts the operator to select sine waveform by pressing <ENTER>

Parameters and Alarm Thresholds

These messages appear when the corresponding parameter and alarm threshold keys are pressed.

Message	Units	Meaning
TIDAL VOL	LITERS	Displays current settings for tidal volume
RESP RATE	BPM	Displays current setting for respiratory rate
PEAK FLOW	Lpm	Displays current setting for peak inspiratory flow
SENS	CMH2O	Displays current setting for sensitivity
OXYGEN	%	Displays current setting for oxygen percentage
PLATEAU	SEC	Displays current setting for plateau
SIGH TV	LITERS	Displays current setting for sigh tidal volume
SIGH HIPL	CMH2O	Displays current setting for sigh high pressure limit
SIGH RATE	PER HR	Displays current setting for sigh rate per hour
HI PRESS	CMH2O	Displays current setting for HIGH PRESSURE LIMIT alarm
LO PRESS	CMH2O	Displays current setting for LOW INSPIRATORY PRESSURE alarm
LO PEEP	CMH2O	Displays current setting for LOW PEEP/CPAP PRESSURE alarm
LO EXH TV	LITERS	Displays current setting for LOW EXHALED TIDAL VOL alarm
LO EXH MV	Lpm	Displays current setting for LOW EXHALED MINUTE VOL alarm
HI RSP RT	BPM	Displays current setting for HIGH RESPIRATORY RATE alarm

Table 2-2. Window Messages and Their Meanings (Continued)

EST Messages (See Chapter 5 for additional messages pertaining to self-test procedures.)

Message	Meaning
START EST ENTER	Asks the operator to verify that EST is to be run
PAT TUBING OFF	Asks the operator to verify that the patient is disconnected from the ventilator
QUICK EST	Prompts the operator to verify that Quick EST (QUEST) is to be run
TOTAL EST	Prompts the operator to verify that Total EST (TEST) is to be run
EST COMPLETE	Indicates that a self-test detected a noncritical error
EST FAIL	Indicates that a self-test detected a critical error
EST PASS	Indicates that a self-test detected neither critical nor noncritical errors
OVERRIDE—ENTER	Prompts the operator to override an EST COMPLETE or EST FAIL state (consult institutional protocol)

I:E Ratio Check Messages

Message	Meaning
CHANGE PK F/TV FIRST	Appears when a change in respiratory rate setting caused an inappropriate I:E ratio. Change the peak inspiratory flow or tidal volume settings before making the respiratory rate change
DECR RESP RATE FIRST	Appears when a change in waveform, tidal volume, peak inspiratory flow or plateau caused an inappropriate I:E ratio. Prompts the operator to decrease the respiratory rate before making the change

Miscellaneous Messages

Message	Meaning
INVALID ENTRY	Parameter or alarm threshold selected is out of its permissible range
APNEA VENTILATION	Apnea was detected and apnea ventilation was invoked
NEB DISCONNECT	Unusually large flow through nebulizer circuit was detected and nebulization was automatically canceled
WXYZ ERR	System error was detected during POST and ventilator is operating in Back Up Ventilator mode. Have ventilator serviced as soon as possible
ERR WXYZ DO NOT USE	System error or fault was detected by Ongoing Checks. For system errors, the message lasts a few seconds, then blanks as POST executes
RUN EST–DO NOT USE	Occurs in conjunction with the [ERR WXYZ DO NOT USE] message. Ongoing Checks detected a system error and initiated POST, but POST failed. The ventilator is in back up ventilator mode and must be serviced
LOW AC POWER	AC voltage to the ventilator has dropped below 90% of the rated value and the ventilator is in back up ventilator mode
SVO DUE TO LSP	Ventilator is in safety valve open because both gas supplies to the ventilator have been lost
AIRWAY PRESS DISCONN	Ventilator detected higher pressure at the inspiratory pressure transducer than expected, based upon the pressure sensed at the exhalation pressure transducer; ventilator switched to disconnect ventilation. A possible cause is disconnected patient tubing.
REVIEW SIGH PARAMS	The <MANUAL SIGH> key was pressed but no sigh parameters have been set.

Utility Panel

The utility panel of the ventilator contains the power switch, EST button, alarm volume control, reset button, and a nine-pin connector. The connector allows for signal output connection to an analog recorder or remote nurse's call.

Figure 2-7 shows the utility panel. Table 2-3 summarizes utility panel functions.

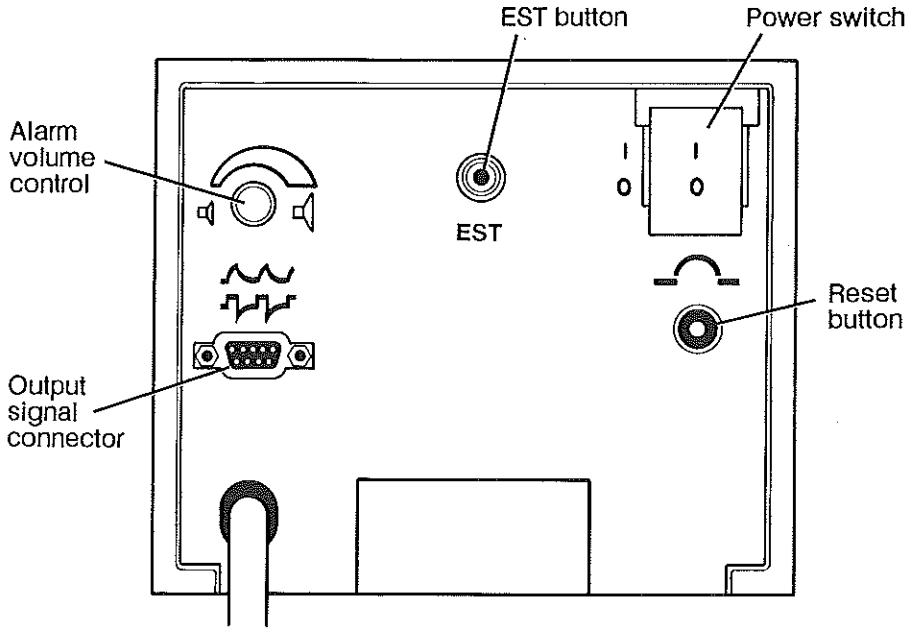


Figure 2-7. Utility Panel

Table 2-3. Function of Ventilator Controls on the Utility Panel

Key, Indicator, or Display	Function
Alarm volume	Allows for adjusting the loudness of the audible alarm
EST	Allows for initiating either Quick Extended Self-Test (QUEST) or Total Extended Self-Test (TEST); not accepted during lamp test, apnea ventilation or disconnect ventilation, or a safety valve open state
Power	Allows for turning the ventilator on and off
Reset	Allows for resetting the circuit breaker
Output signal	Provides analog signals of flow and pressure signals for a recording device and connects to a remote nurse's call

Normal Operation Description of Ventilator Breath Types

The ventilator produces two breath types, mandatory and spontaneous. All ventilator modes are composed of these two breath types, alone or in combination, as well as modifications of these types.

Mandatory Breath

A mandatory breath is a positive pressure breath which can be initiated by the operator, ventilator, or patient. The operator selects the waveform, tidal volume, peak inspiratory flow, percentage of oxygen, plateau (if desired), and respiratory rate for these breaths. Ventilator-initiated breaths (Figure 2-8, Panel A) are delivered at a constant cycle interval determined by the operator-selected value for respiratory rate. Operator-initiated breaths are one-time events that occur when <MANUAL INSPIRATION> (Figure 2-8, Panel B) or <MANUAL SIGH> is pressed. (These keys are honored at any time during the normal breath cycle except during a mandatory inspiration.) Patient-initiated breaths (Figure 2-8, Panel C) are delivered whenever patient effort reduces the airway pressure below PEEP by an amount equal to the operator-selected value for sensitivity.

The ventilator also delivers a special type of mandatory breath called a sigh breath, which is specified by the sigh function. Sigh has four operator-selectable parameters: sigh tidal volume, sigh high pressure limit, sigh events per hour, and multiple sighs per sigh event.

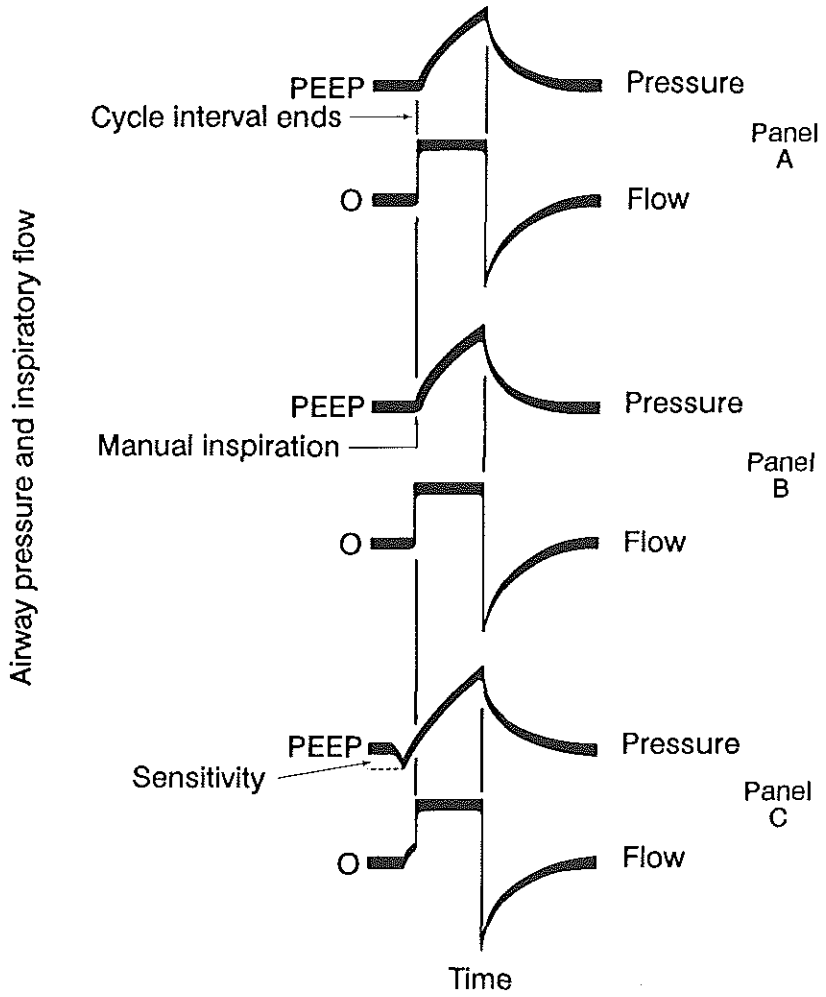


Figure 2-8. Initiation of a Mandatory Breath

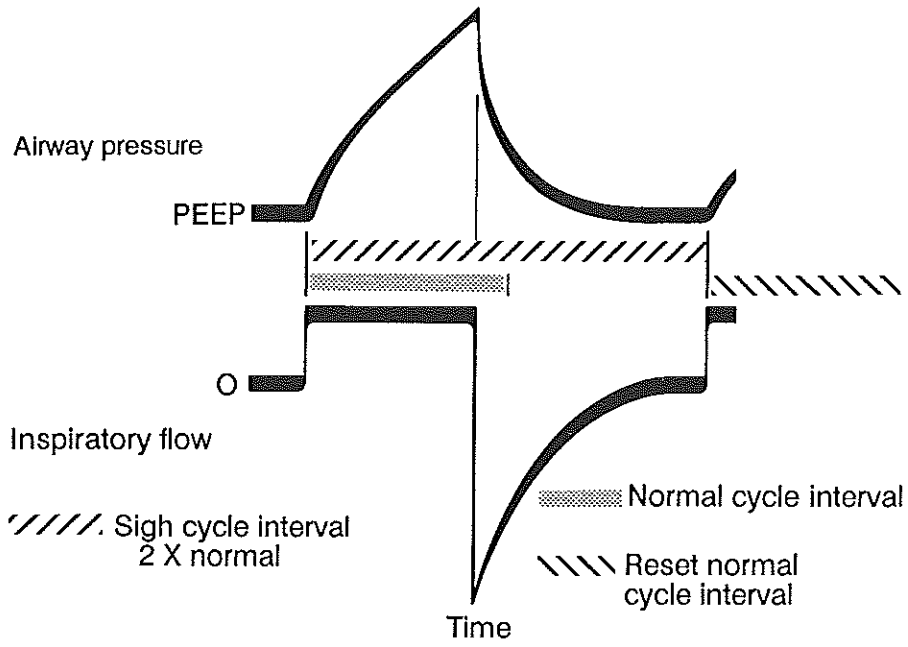


Figure 2-9. Characteristics of a Sigh Breath

The characteristics (peak inspiratory flow, waveform, plateau, and oxygen composition) of a sigh breath correspond to those of a mandatory breath (see Figure 2-9). A sigh can be initiated by the operator or the patient in any ventilatory mode. A ventilator-initiated sigh can occur in any mode except CPAP.

In general, the sigh cycle interval is equal to twice the normal cycle interval. An exception exists when the apnea interval is less than twice the normal cycle interval. In this case, the sigh cycle interval is terminated and apnea ventilation takes effect.

Unless sigh tidal volume has been set to zero (which turns off the sigh function), one sigh tidal volume is delivered each time the <MANUAL SIGH> key is pressed. Sigh breaths cannot be delivered unless sigh parameters have been set via <AUTOMATIC SIGH>.

Spontaneous Breath

A spontaneous breath is always initiated by the patient. In a spontaneous breath the flow of inspiratory gas and the tidal volume are determined solely by patient effort. However, the operator selects the oxygen composition, using the O_2% parameter. In addition, operator settings for PEEP and sensitivity determine the airway pressure level at which gas flow is triggered.

Description of Ventilator Modes

The 7200ae Ventilator offers three ventilatory modes—Continuous Mandatory Ventilation, Synchronous Intermittent Mandatory Ventilation, and Continuous Positive Airway Pressure. These modes determine the type of breath and sequence of breaths to be delivered.

Ventilator options modify the three basic modes of ventilation provided with the 7200ae Ventilator. Theory and operating instructions are provided in the option's appendix.

Continuous Mandatory Ventilation (CMV): During CMV, all breaths are mandatory. They may be either ventilator-, operator-, or patient-initiated.

Synchronous Intermittent Mandatory Ventilation (SIMV): During SIMV, breaths may be either mandatory or spontaneous. Mandatory breaths may be ventilator-, operator-, or patient-initiated; spontaneous breath are patient-initiated.

Continuous Positive Airway Pressure (CPAP): During CPAP, all breaths are spontaneous, except for operator-initiated mandatory breaths (both normal and sigh) and patient-initiated sigh breaths (with the automatic sigh feature).

Table 2-4 shows the breath types available in each mode.

Table 2-4. Breath Types for Each Mode

	CMV	SIMV	CPAP
Ventilator-initiated mandatory (VIM)	Yes	Yes	No
Patient-initiated mandatory (PIM)	Yes	Yes	Yes (automatic sigh only)
Operator-initiated mandatory (OIM)	Yes	Yes	Yes
Spontaneous	No	Yes	Yes

Operation During CMV Mode

Figure 2-10 illustrates the types of breaths possible during CMV: ventilator-, operator-, and patient-initiated. In the absence of operator or patient initiation, the ventilator delivers a mandatory breath at the end of the cycle interval (events labeled "a"), calculated from the set respiratory rate. The following formula illustrates this calculation:

$$\text{Cycle interval} = \frac{\text{1 minute (60 seconds)}}{\text{respiratory rate (number of breaths per minute)}}$$

A patient may breathe more frequently than the set respiratory rate by producing inspiratory efforts sufficient to trigger a PIM breath prior to the end of the CMV cycle interval (e events). An insufficient inspiratory effort (event d) has no effect on the normal delivery of VIM breaths. A PIM breath resets the cycle interval.

An operator-initiated manual inspiration or manual sigh may be delivered at any time during the cycle interval except during a mandatory inspiration. Delivery of an operator-initiated mandatory breath (event c) automatically resets the cycle interval as shown in Figure 2-10. Depending on the conditions that triggered the sigh breath, the sigh will either be ventilator-initiated (event b) or patient-initiated (event f).

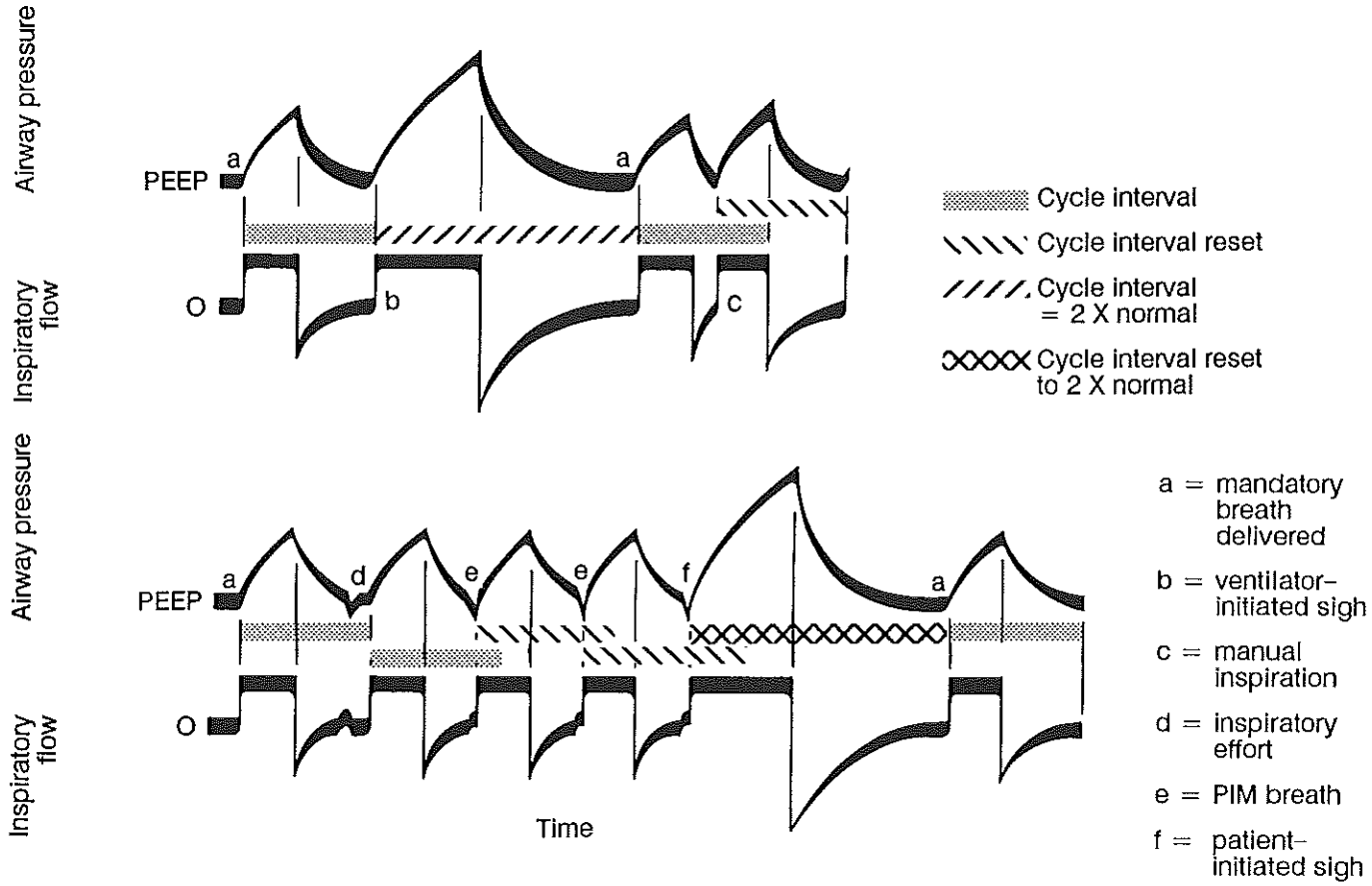


Figure 2-10. Initiation of Different Types of Mandatory Breaths During CMV

Operation during SIMV Mode

During SIMV, breaths may be mandatory or spontaneous and are synchronized to patient effort. Whether a patient-initiated breath is mandatory or spontaneous depends on where the patient effort occurs during the SIMV cycle. The SIMV cycle is composed of two phases: the patient-initiated mandatory (PIM) phase and the spontaneous phase (see Figure 2-11).

In the PIM phase, a patient-initiated inspiration (event a) results in a synchronized, PIM breath. After the breath is delivered, the PIM phase of the cycle ends and the spontaneous phase begins. Any inspiratory effort by the patient sufficient to trigger an inspiration during the spontaneous phase results in a spontaneous breath (b events). With the completion of the spontaneous phase, the SIMV cycle ends. The next cycle begins in a new PIM phase.

For example, if the respiratory rate is set to 12 bpm (a cycle interval of 5 seconds), a PIM could occur at any point in that interval. Once the patient has initiated a mandatory breath, the ventilator allows spontaneous breathing as often as desired for the remainder of the interval.

If no PIM breath is delivered during the PIM phase, the spontaneous phase does not begin and the PIM phase continues to the end of the cycle. A ventilator-initiated mandatory breath (VIM) is delivered at the start of the next SIMV cycle and another PIM phase begins. (See Figure 2-11 and Figure 2-12.) If no PIM breath occurs during that PIM phase, the next cycle begins again with another VIM breath. However, if the patient initiates a mandatory breath during the PIM phase, the re-

mainder of the cycle interval continues in the spontaneous phase. The next SIMV cycle begins in a PIM phase.

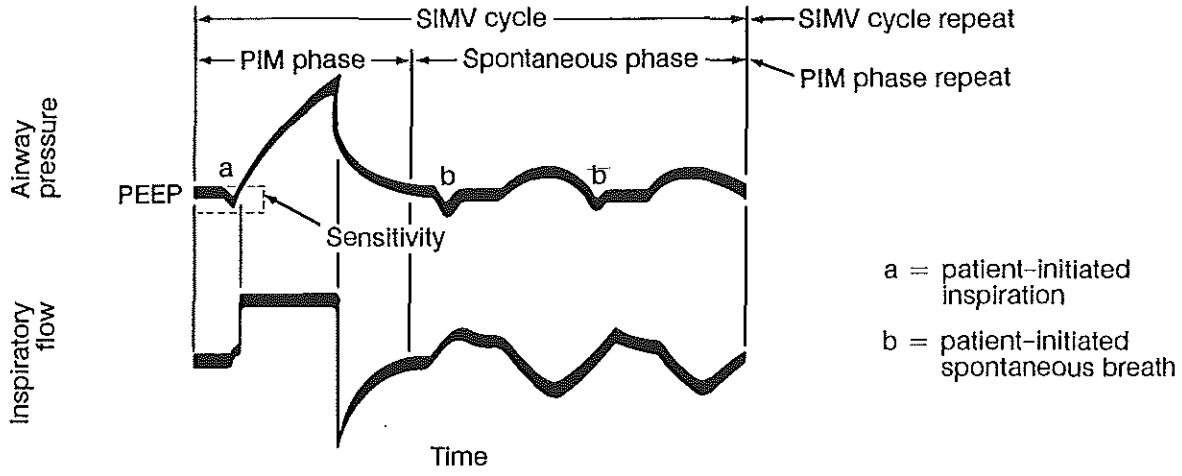


Figure 2-11. Breath Patterns During SIMV, Adequate Inspiratory Effort

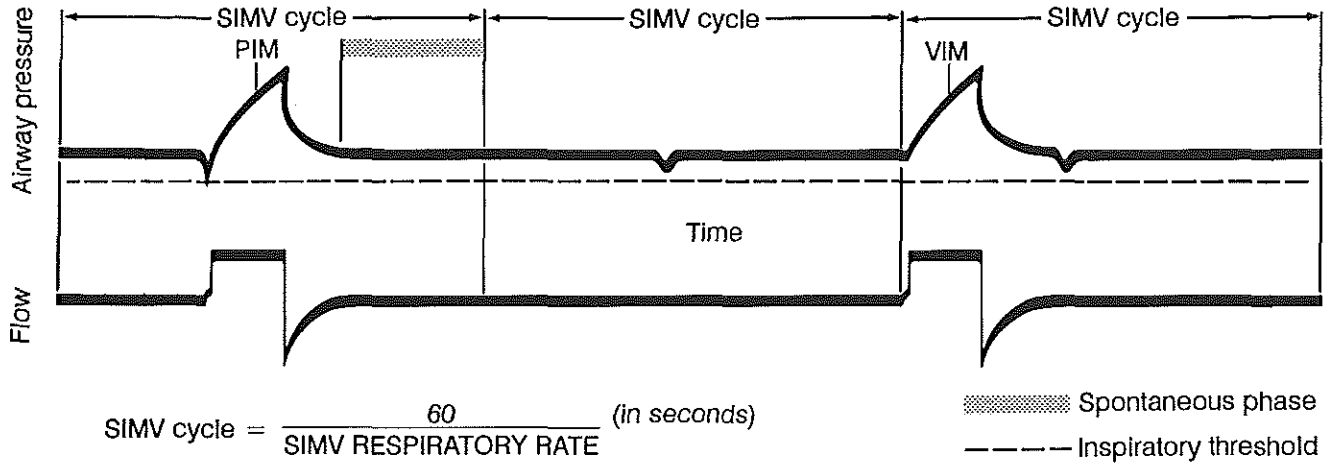


Figure 2-12. Breath Patterns During SIMV, Inadequate Inspiratory Effort

When the patient discontinues initiation of mandatory breaths during the SIMV cycle, the total time between the last successful patient-initiated mandatory breath and the ventilator-initiated mandatory breath may approach two SIMV cycle intervals. As a result, if the respiratory rate is set to 2 bpm or less, and the patient ceases initiating

spontaneous breaths, a period exceeding the apnea interval (a maximum of 60 seconds) may elapse between breaths. This would cause the ventilator to detect apnea and begin apnea ventilation.

> ***WARNING*** – *It is important to be attentive to the current settings for apnea parameters so they are appropriate for the patient. The apnea interval should be based on what the practitioner considers to be an unsafe period between breaths. Note that if the apnea interval exceeds twice the SIMV cycle, the ventilator may not detect apnea because ventilator breaths would be delivered before the apnea interval passes.*

After a change from CMV to SIMV, the ventilator automatically begins the timing for the first SIMV cycle. Time remaining from the preceding CMV cycle is ignored.

If this additional time is likely to cause the ventilator to declare apnea and possibly apnea ventilation, press <MANUAL INSPIRATION> after the ventilator enters the SIMV mode. This causes the ventilator to deliver an operator-initiated mandatory breath and simultaneously sets the first SIMV cycle. This situation is illustrated in Figure 2-13.

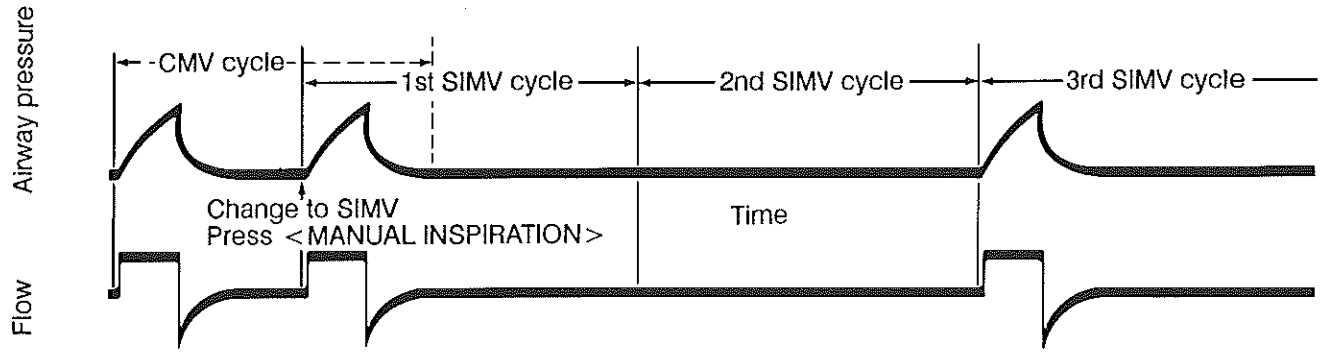


Figure 2-13. Resetting the Cycle Interval When Changing from CMV to SIMV

Operation During CPAP Mode

During CPAP, patients are assumed to be breathing spontaneously at a rate sufficient to meet their ventilatory requirements. To supplement patient effort, the operator may select <AUTOMATIC SIGH>, <MANUAL SIGH>, or <MANUAL INSPIRATION>. In general, these breaths are honored in the CPAP mode at any time during the cycle interval. If the high pressure limit is exceeded during a manual inspiration, triggering the HIGH PRESSURE LIMIT alarm (or if the sigh high pressure limit is exceeded during a sigh inspiration), breath delivery is terminated immediately.

Delivery of a Mandatory Breath

Figure 2-14 shows how the pneumatic system works during a mandatory breath.

Current settings for waveform, tidal volume, peak inspiratory flow, and O_2% are used to calculate the gas flow for the specified breath. The setting for respiratory rate determines the minimum frequency of breathing and the cycle interval. When gas flow is initiated or termi-

nated by the opening and closing of the proportional solenoid valves, the delivered flow is monitored and converted to a volume measurement at body temperature and pressure and 100% saturation with humidity (BTPS). (Accuracy of the BTPS calculation assumes that the gas leaving the patient wye is 100% humidified at 37° C.) Microprocessor electronics controls delivered flow by comparing actual flow with desired flow and adjusting the proportional solenoid valves if any discrepancies between actual and desired flows exist.

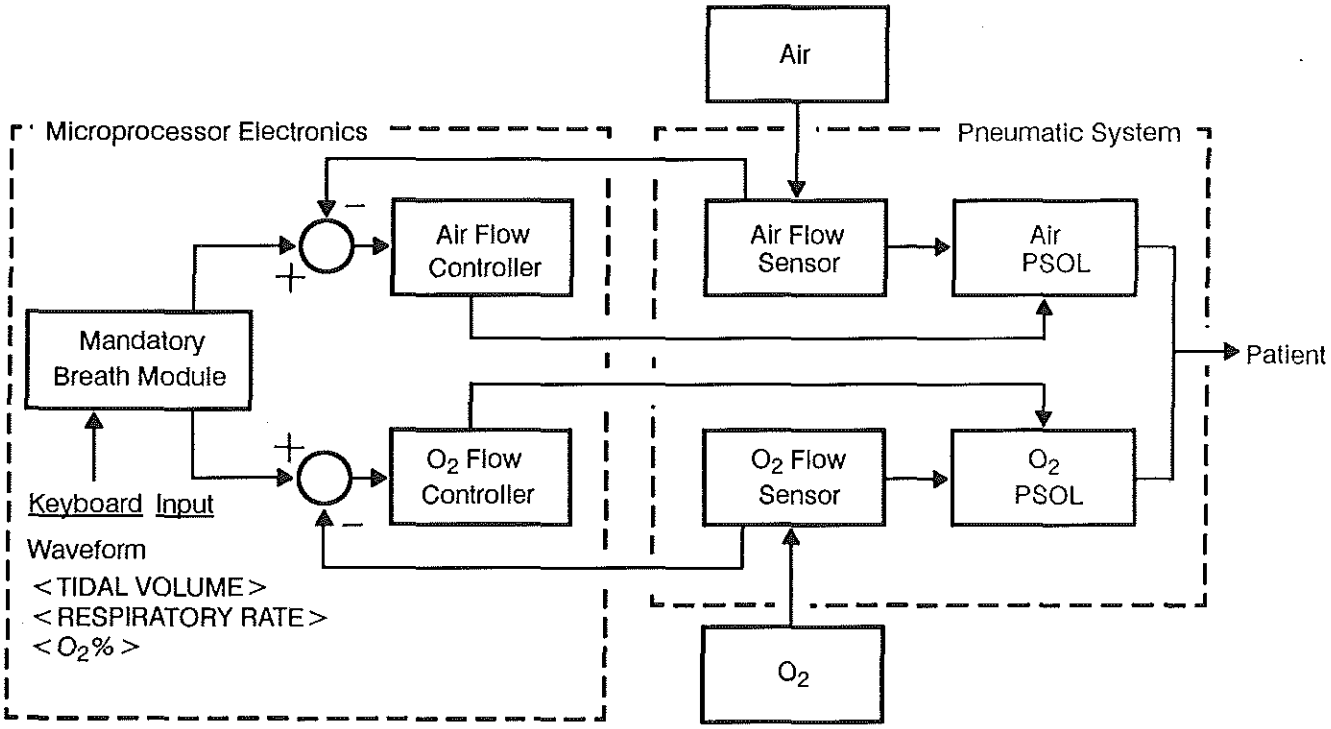


Figure 2-14. Pneumatic System in a Mandatory Breath

As shown in Figure 2-15, each mandatory breath is corrected for compliance of the patient circuit by adjusting peak inspiratory flow. Compliance volume is added to each delivered tidal volume. This volume is obtained by multiplying a compliance value by the average peak airway pressure of the last four mandatory breaths. The compliance value is calculated during EST. This compliance volume correction ensures that the patient receives the operator-selected BTPS corrected tidal volume.

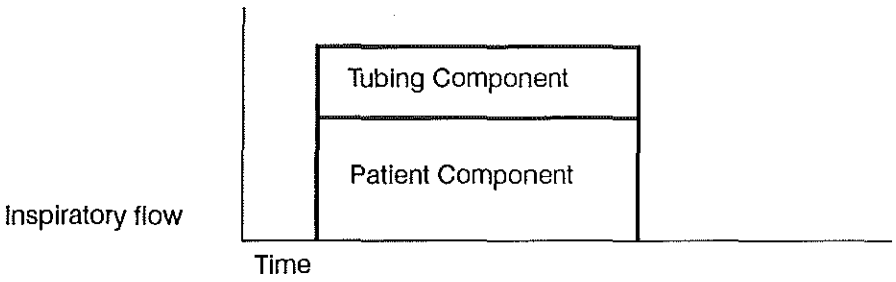
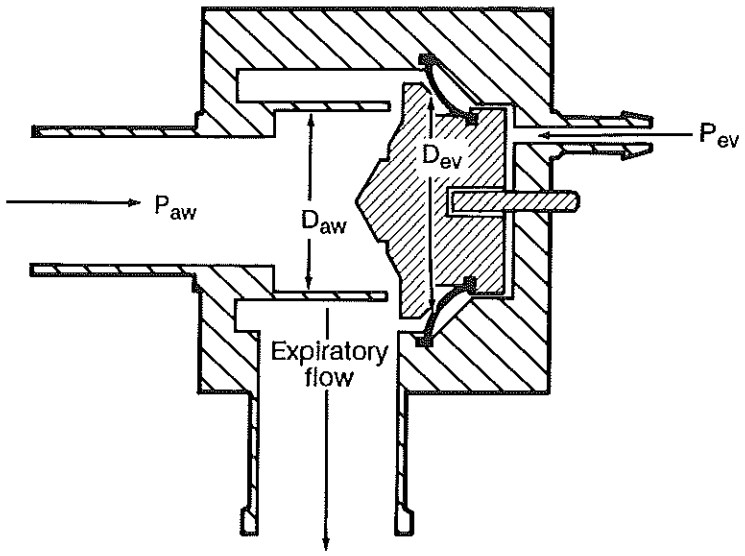


Figure 2-15. Compensation for Compliance Volume During the Delivery of a Mandatory Breath

The exhalation valve ensures gas delivery by sealing the exhalation port during inspiration. As shown in Figure 2-16, the valve opens for exhalation when opening force (based on P_{aw}, airway pressure) is greater than closing force (based on P_{ev}, exhalation valve pilot pressure). In Figure 2-16, D_{aw} and D_{ev} are distances used to calculate area ratio during EST.

The exhalation valve is also the source of the area ratio value, which is used in calculations for breath delivery. During EST, a fixed pressure, P_{aw}, is measured. The ratio of these two pressures is the area ratio value. The ratio of the distances D_{aw} and D_{ev} ,shown in Figure 2-16, approximates the area ratio.



$Force_{open} = P_{aw} \times area_{Daw}$ $Force_{close} = P_{ev} \times area_{Dev}$

If $P_{aw} = P_2$, then $force_{open} < force_{close}$

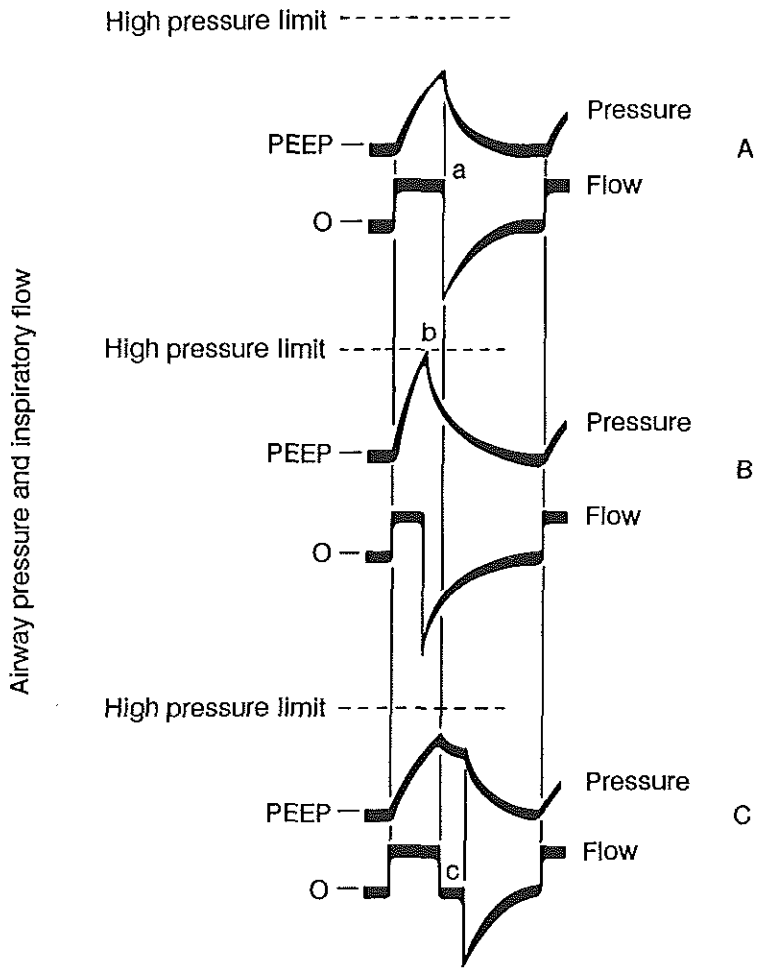
If $force_{open} = force_{close}$ then $P_{aw} \times area_{Daw} = P_{ev} \times area_{Dev}$

$$\frac{P_{aw}}{P_{ev}} = \frac{area_{Dev}}{area_{Daw}} = \frac{area}{ratio}$$

Figure 2-16. Cross Section of the Internal Exhalation Valve

As shown in Figure 2-17, a mandatory breath is terminated when the desired volume has been delivered (panel A, event a) or when the high pressure limit is reached (Panel B, event b). Exhalation is initiated when either of these events occurs. Exhalation occurs by venting the exhalation valve to the PEEP level. This level equals atmospheric pressure when PEEP equals zero cmH_2O. A check valve prevents backflow through the inspiratory limb of the patient circuit. During normal operation, PEEP exhalation valve pressure is supplied by air rather than oxygen (unless air supply is lost and only oxygen is available).

If you have selected plateau (an inspiratory pause), cessation of inspiratory flow does not immediately trigger exhalation. Instead, exhalation is delayed for the selected plateau interval (Figure 2-17, Panel C, event c). Plateau is considered an extension of inspiration. If the high pressure limit is reached during a plateau, then both inspiration and plateau are terminated and exhalation begins.



a = tidal volume delivered

b = high pressure limit reached

c = *plateau interval*

Figure 2-17. Termination of a Mandatory Breath

Delivery of a Spontaneous Breath

Figure 2-18 illustrates how the pneumatic system works during a spontaneous breath.

Compare Figure 2-14 and Figure 2-18. Note that for mandatory breaths, flow, waveform, and time, are controlled. For spontaneous breaths, airway pressure is controlled and maintained within narrow limits by adjusting flow.

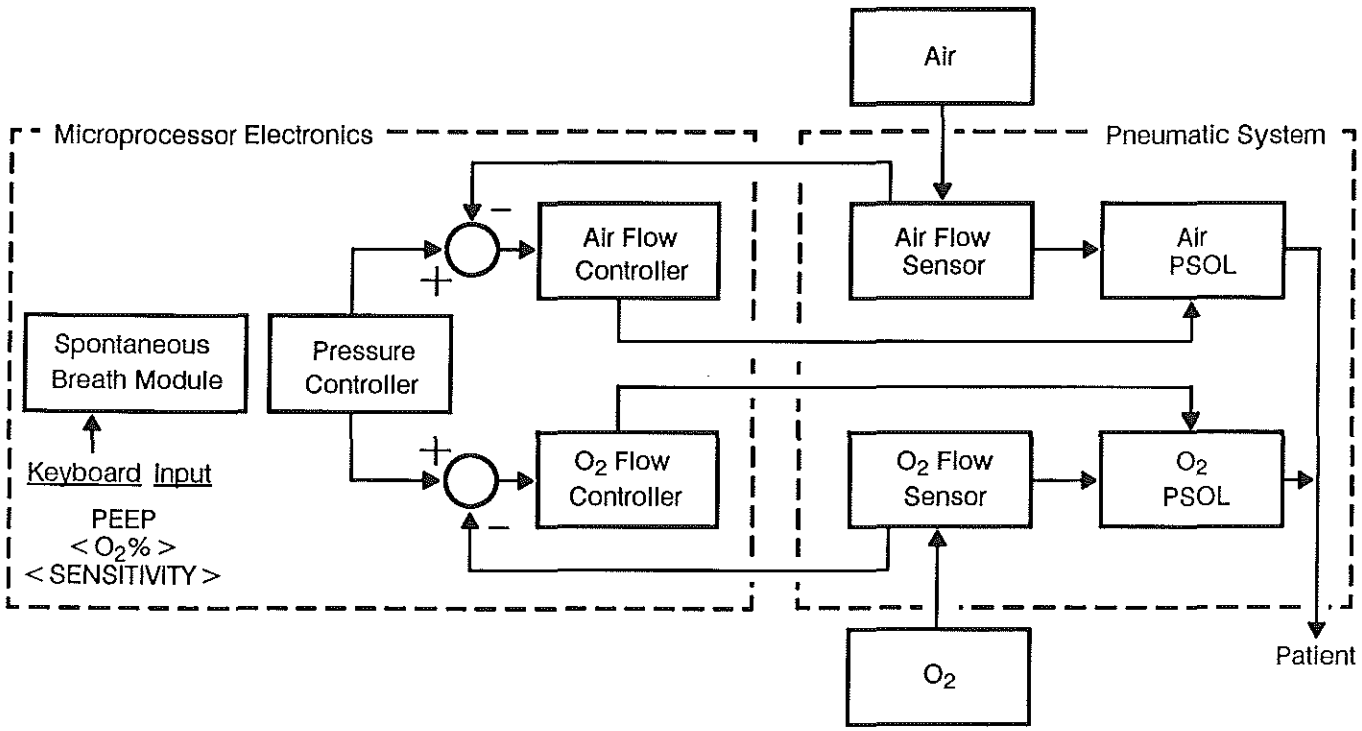
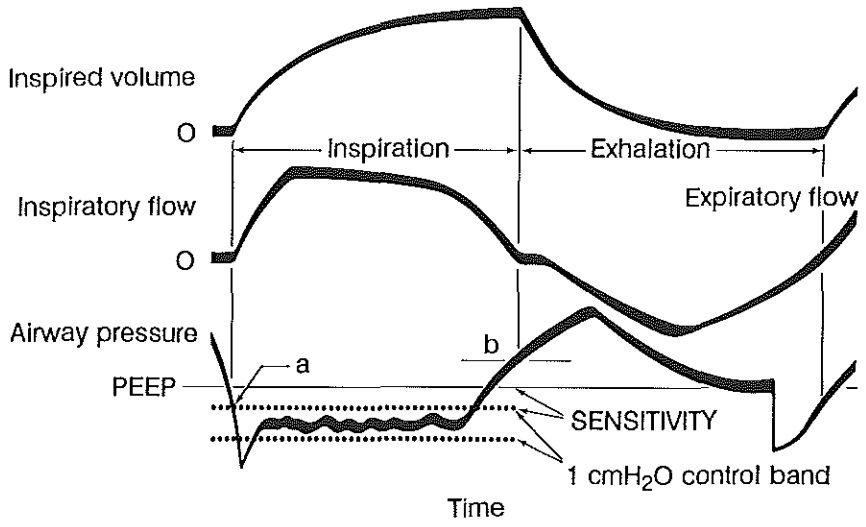


Figure 2-18. Pneumatic System in a Spontaneous Breath

Figure 2-19 shows that when patient effort reduces airway pressure below PEEP by an amount equal to sensitivity (event a), flow is triggered. Microprocessor electronics maintains airway pressure between the amount of the triggering pressure and a value which is 1 cmH_2O below it. When airway pressure exceeds PEEP by approximately 1 cmH_2O (event b), the exhalation valve is unseated to PEEP, and exhalation occurs. A spontaneous breath cycle terminates when the next breath occurs.



a = airway pressure decreased by sensitivity

b = airway pressure exceeds PEEP by ~1 cmH_2O

Figure 2-19. Pressure, Flow, and Volume During a Spontaneous Breath

Calculation of PEEP and Breath Delivery

The accuracy of the PEEP value is important for proper breath delivery. The inspiratory threshold, the pressure at which the pneumatic system is activated to deliver a breath, is equal to PEEP minus the sensitivity setting. Therefore, if PEEP is incorrect, breath delivery may be triggered inappropriately.

PEEP is calculated by multiplying area ratio by the pressure on the ventilator side of the exhalation valve (P_{ev} in Figure 2-16). The area ratio value used in determining PEEP is obtained during EST. See Chapter 5 for more complete information on performing EST procedures.

Nebulization

Nebulization occurs only during an inspiration and lasts a maximum of 30 minutes. No nebulization occurs during plateau or when flow to the patient is less than 10 Lpm.

WARNING – *The nebulizer requires approximately 10 Lpm of flow to ensure reliable operation. Therefore, if you select any combination of peak inspiratory flow and O_2% that would yield less than 10 Lpm through the solenoid supplying the nebulizer circuit, microprocessor electronics senses the low flow and deactivates the solenoid supplying the nebulizer. The light on the nebulizer key, however, will remain illuminated.*

While a breath is being delivered, high pressure air or oxygen is diverted through the nebulizer circuit. The air or oxygen proportional solenoid valves close slightly to compensate for this extra volume of gas going to the patient through the circuit. The ventilator determines the gas source to be diverted based on the predominant gas flow. If the O_2% is 60 or greater (that is, whenever oxygen flow is equal to or greater than air flow), oxygen is diverted to the nebulizer. Otherwise, air is diverted.

If the value for peak inspiratory flow through the solenoid supplying the nebulizer circuit is only slightly greater than 20 Lpm during the mandatory breath, the duration of nebulization will depend on the waveform. When the square wave is selected (Figure 2-20, Panel A), nebulization will last for the entire breath, excluding any plateau period. When descending ramp or sine wave is selected (Panels B and C, respectively), nebulization will last only for the interval during which the projected flow from the gas source supplying pressure to the nebulizer circuit exceeds 10 Lpm. Once selected, nebulization remains on for 30 minutes, then automatically cancels. It can be canceled manually before 30 minutes have elapsed.

If either one of the gas supplies falls below the minimum operating pressure (35 psig for wall gas, 7.5 psig for the compressor pedestal), nebulization is suspended until at least the minimum operating pressure is restored.

Nebulization is automatically suspended in case of apnea ventilation or disconnect ventilation.

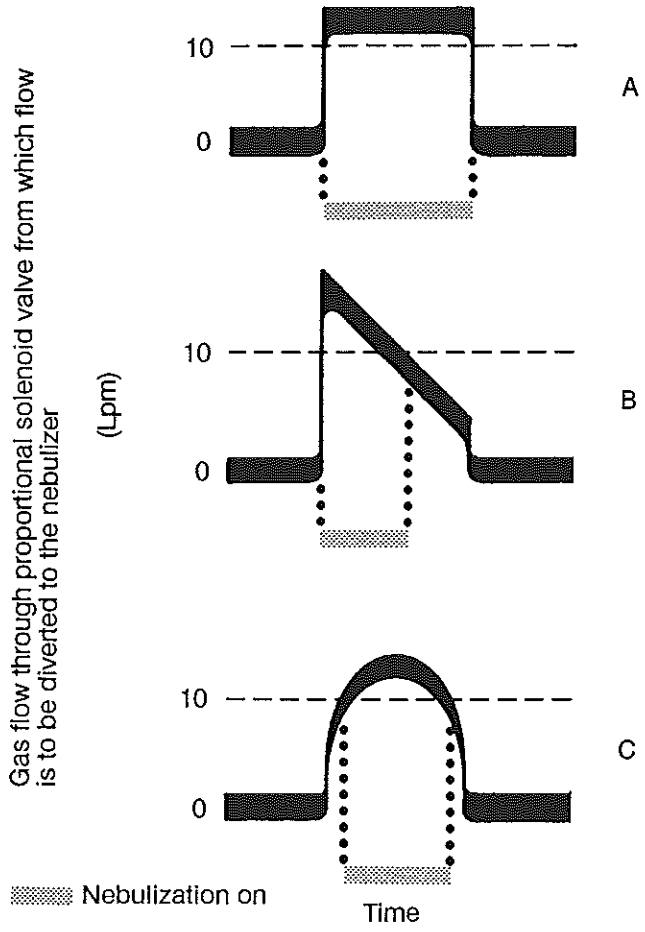


Figure 2-20. Duration of Nebulizer at Low Peak Inspiratory Flows

Humidification System

The ventilator will accept any plug-compatible humidifier with a rating of 230 watts or less. Since the 7200ae Ventilator does not control the humidifier circuit, it is important that any humidifier used has its own temperature control mechanism, display, and alarm.

WARNING – *If power consumption is greater than 230 watts, the ventilator's circuit breaker may open and interrupt power. If this happens, the ventilator goes into Safety Valve Open, the patient breaths room air unassisted by the ventilator, and a power disconnect alarm triggers.*

The ventilator calculates spirometry based on assumptions that the exhaled gas is 37 C° and saturated with 100% relative humidity at the patient wye. Discrepancies in spirometry readings may arise if conditions do not match these assumptions, especially if a heated humidifier is not used, or is not allowed sufficient warm-up time.

NOTE – For the most accurate spirometry readings, use a heated humidifier, like the Cascade Series Humidifiers.

Displayed Patient and Ventilator Data and Calculations

Microprocessor electronics uses signals from flow, pressure, and temperature sensors (both inspiratory and expiratory) to calculate and display volumes, pressures, respiratory rate, and I:E ratio. All the displayed values reflect patient data and ventilator status. The calculations are described below.

Volume Calculations

Information from both the pneumatic and patient service systems is used to determine the end of inspiration (beginning of exhalation) and the end of exhalation (beginning of inspiration). When the ventilator determines that inspiration has ended, it begins integrating exhaled flow. Integration continues until the start of a new breath cycle. When a new inspiration is detected, integration stops, the value is stored as exhaled tidal volume (uncorrected for BTPS or compliance volume), and is used in spirometric calculations. The integration of exhaled flow is automatically set to zero. This applies to both mandatory and spontaneous breaths.

The ventilator declares the end of inspiration differently depending on the type of breath delivered. *During a mandatory breath, the end of* inspiration is defined as either 1) the time at which the operator-selected tidal volume has been delivered or 2) the time at which airway pressure is greater than the high pressure limit, even if the tidal volume has not yet been delivered. When the exhalation flow sensor detects a flow greater than 2 Lpm after the end of inspiration, it begins integrating flow.

When plateau is selected for a mandatory breath, the resulting inspiratory pause is considered part of the delivery of a breath. Therefore, for a breath which includes a plateau, inspiration does not terminate until the end of the plateau. However, the ventilator may terminate the *inspiration period prematurely if the HIGH PRESSURE LIMIT alarm is* triggered.

During a spontaneous breath, microprocessor electronics checks for the end of inspiration based on whether airway pressure increases beyond PEEP by 1 cmH_2O.

NOTE – On the Basic keyboard, the exhaled volume displayed by the analog meter equals the total exhaled volume without adjustment for compliance volume and without correction to BTPS. Therefore, exhaled volume on the analog meter and tidal volume in the digital display may differ. The amount of discrepancy between these values depends on peak airway pressure, compliance of the patient circuit, temperature of exhaled gas, and ambient barometric pressure.

Tidal Volume: The BTPS-corrected value for exhaled tidal volume appears in the liters digital display window. It is an eight-breath running average for mandatory breaths. If a breath is not within 50 ml of the average of the volume for the eight mandatory breaths, the display shows only the current breath volume, not an average. Tidal volume for spontaneous breaths is always displayed, regardless of the average. It is updated and displayed at the end of each exhalation.

Minute Volume and Spontaneous Minute Volume: The mandatory and spontaneous exhaled volume data displayed are based on an eight-breath projected running average or a one-minute sample, whichever occurs first. The mandatory minute volume and spontaneous minute volume are calculated separately at the end of each breath cycle. Both minute volumes display at the completion of a breath cycle.

Airway Pressure Calculations

In calculating airway pressures, microprocessor electronics measures the airway pressure in the patient service system at discrete times. By taking these measurements frequently, microprocessor electronics receives a nearly continuous signal from the pressure transducers.

Mean Airway Pressure: The airway pressure averaged over all measurements made during an entire breath cycle (inspiration and exhalation) for mandatory and spontaneous breaths. Mean airway pressure is updated and displayed at the end of each subsequent breath cycle. It is blanked whenever the ventilator is turned on. Only positive values of mean airway pressure are recorded. Negative values are reported as zero.

Peak Airway Pressure: The maximum airway pressure measured in the patient service system during a mandatory breath. Peak airway pressure is updated and displayed at the end of each inspiration. It is blanked during CPAP after < ALARM RESET > is pressed until the next mandatory breath.

PEEP/CPAP: The pressure applied to the ventilator side of the exhalation valve multiplied by the area ratio (see Figure 2-16). The PEEP/CPAP pressure is displayed on a continuous basis.

Plateau Pressure: The average of the last four pressure sample measurements made during plateau. Plateau pressure is displayed at the end of each plateau.

The PLATEAU PRESSURE digital display is blanked when the plateau interval is 0 seconds.

Miscellaneous Calculations

Rate (bpm): The average of the rate of breathing calculated for a patient's previous 10 breaths, regardless of breath type. The calculation is updated and displayed at the end of each exhalation. The respiratory rate is blanked when the ventilator is turned on.

I:E Ratio: Available for display in the RATE/I:E window as 1:X.X. The term X.X is calculated by dividing the time for exhalation by the time for inspiration:

$$X.X = \frac{E}{I}$$

Therefore, the I:E ratio is 1:X.X. The exhalation time, E, is calculated by subtracting the inspiratory time, I, from the total cycle interval measured from the beginning of inspiration to the end of exhalation.

I:E ratio is calculated for mandatory breaths only and is displayed at the end of each breath cycle. During CPAP, the I:E ratio is retained from the last mandatory breath delivered; if < ALARM RESET > is pressed, the display is blanked until the next mandatory breath. During SIMV or CMV, the I:E ratio may vary even though ventilator settings are unchanged if the patient triggers a breath during exhalation.

Analog Meter

Airway pressure (cmH_2O): The pressure measured in the patient service system and displayed continuously during a breath cycle.

Exhaled Volume (liters): *(Available only in the Basic keyboard.)* The continuous integration of the total flow through the exhalation flow sensor, uncorrected to BTPS. The displayed volume includes that volume exhaled by the patient and, during mandatory breaths, that delivered by the pneumatic system to compensate for the compliance volume of the patient service system.

Breath-Type Indicators

The ASSIST indicator illuminates during a patient-initiated mandatory inspiration and cancels at the beginning of exhalation. The SPONTANEOUS indicator illuminates whenever the patient initiates a spontaneous inspiration and cancels at the beginning of exhalation. The SIGH indicator illuminates at the beginning of a sigh breath and cancels at the beginning of the next non-sigh breath. The PLATEAU indicator illuminates when plateau begins and cancels when plateau ends.

Safety Features

Self-Diagnostics

The self-diagnostics include Power-on Self-Test (POST), Quick Extended Self-Test (QUEST), Total Extended Self-Test (TEST), and Lamp Test. The self-tests are under microprocessor control and, with the exception of QUEST and TEST, require minimal involvement on the part of the operator. These tests can indicate what may be faulty with the ventilator. Use the ventilator's self-diagnostics to determine whether the ventilator is operational before using it on a patient. A qualified service technician should do any troubleshooting if the ventilator is nonoperational.

Power-On Self-Test (POST): A series of tests, lasting about 5 seconds, that check microprocessor electronics. If POST detects an error, it halts and puts the ventilator into back up ventilator mode. Back up ventilator mode activates audible and visual alarms and displays the window message, [RUN EST – DO NOT USE]. If POST detects no errors, and the operator has not pressed the < EST > button to initiate a self-test, the ventilator automatically begins operating.

WARNING *– When POST is running, the safety valve is open and the patient breaths room air unassisted by the ventilator.*

Quick Extended Self-Test (QUEST): A 1-1/2 minute test that executes 26 of the approximately 60 test sequences run during TEST. QUEST tests battery-backed memory, cross-checks the differential, absolute, and PEEP pressure transducers, leak-tests the patient service circuit, and calculates the compliance of the patient service system and the area ratio of the exhalation valve. QUEST should be performed whenever the patient service circuit is changed.

Total Extended Self-Test (TEST): a 3 to 5 minute test that executes over 60 test sequences. TEST provides a thorough testing of the ventilator's microprocessor electronics and pneumatic system, including the proportional solenoid valves, the compressor pedestal, and the nebulizer circuit. In addition, it calculates the compliance of the patient service system (for use in determining the compliance volume compensation during the delivery of a mandatory breath). It also detects leaks in the patient service system. TEST should be performed before each new patient is placed on the ventilator.

WARNING – *NEVER INITIATE EST WHILE A PATIENT IS CONNECTED TO THE VENTILATOR. The 7200ae Ventilator cannot be used for ventilatory support while QUEST or TEST is running because it does not function as a normal ventilator during these tests. In addition, some of the procedures that are performed during EST require airway pressures or gas flows that may injure a patient connected to the ventilator.*

POST runs at the beginning of QUEST and TEST. If the ventilator passes POST, QUEST (or TEST) runs three tests to determine whether a patient is connected to the ventilator. These tests must pass before the respective QUEST (or TEST) sequences begin. If any test in QUEST (or TEST) is failed, an explanatory error message appears in the message window.

Refer to Chapter 5 of this manual for details on running QUEST and TEST.

Lamp Test: Checks all keyboard display panel lamps in six groupings. In addition, lamp test checks the audible alarm, the remote Nurse's Call, and the analog signal outputs. Lamp test takes 40 seconds to complete. It is recommended that lamp test be run in conjunction with both QUEST and TEST. During lamp test, an alarm state only triggers the audible alarm; visual indicators may not be available. The <ALARM SILENCE> key is also inactive. Lamp test automatically cancels when any key is pressed, or under the following emergency or alarm conditions:

- apnea ventilation
- disconnect ventilation
- back up ventilator
- VENTILATOR INOPERATIVE and SAFETY VALVE OPEN
- nebulizer disconnect
- power disconnect

For all other alarms or emergency states, the audible alarm will sound and lamp test will continue to run. Neither the individual alarm indicator nor ALARM in the alarm summary display will flash. Any effects on ventilation that are normally associated with the detection of the alarm or emergency state (for example, termination of a mandatory breath when a HIGH PRESSURE LIMIT alarm is triggered) will occur if an alarm is detected during lamp test.

Ongoing Functional Checks

Additional checks take place during normal ventilation without operator intervention: I:E Ratio Check, Nebulizer Flow Check, and Ongoing Checks.

I:E Ratio Check: A check made by microprocessor electronics after any change in the operator-selected parameters (tidal volume, respiratory rate, peak inspiratory flow, plateau, or waveform). The I:E Ratio Check ensures that the calculated duration of the inspiration is less than 75% of the cycle interval. The check calculates the duration of the inspiration and compares this to the cycle interval, as determined from the respiratory rate. If the calculated duration of the inspiration takes up 75% (I:E = 1:0.3) or more of the total cycle interval, the ventilator will reject the newly selected value. Prompts will appear in the message window instructing the operator to make changes in the appropriate parameters to yield an inspiratory period which is less than 75% of the total cycle interval.

Nebulizer Flow Check: A check made by microprocessor electronics to determine that the flow of gas through the nebulizer valve is not excessive. The check is made every eight breaths. A nebulizer check operates as described below:

1. The nebulizer valve is left open for 20 to 40 milliseconds.
2. The flow through the nebulizer valve is measured. When measured flow exceeds maximum rate, Nebulizer Disconnect is declared; the nebulizer function is suspended and [NEB DISCONN] appears in the message window.

Ongoing Checks: These checks routinely monitor the ventilator for system faults and system errors during operation. Faults are conditions that jeopardize the ventilator's ability to control the delivery of gas to the patient. Examples of system faults are out-of-range or inconsistent readings from the proportional solenoid valves, flow sensors, and the pressure transducers, and readings from the gas supply circuitry indicating that the ventilator is being supplied simultaneously from both air sources (wall and compressor).

When the Ongoing Checks detect a system fault, the ventilator ceases to operate, and the safety valve opens; the patient breathes room air, unassisted by the ventilator. Both SAFETY VALVE OPEN and VENTILATOR INOPERATIVE illuminate in the alarm summary display and the audible alarm sounds. The ventilator must be serviced before it is used again. If a system fault occurs before POST is run, the ventilator also goes into SAFETY VALVE OPEN state.

System errors are conditions that do not necessarily jeopardize the ability of the ventilator to control the delivery of gas. When the Ongoing Checks detect a system error, POST runs and the safety valve opens during the test. (If the ventilator's memory records three system errors in a 24-hour period, the ventilator initiates the back up ventilator mode and activates audible and visual alarms.) If the ventilator passes POST, it automatically resumes normal operation using the current settings. If the ventilator fails POST, it enters the back up ventilator mode. BACK UP VENTILATOR illuminates in the alarm summary display and the audible alarm sounds.

See Table 2-5 for an overview of the self-tests and ongoing checks.

Table 2-5. Overview of Self-Tests and Ongoing Checks

Test	How Invoked	What Happens if the Ventilator Fails Test	Operator Responses if the Ventilator Fails Test
POST	• At initial power-on • After any power interruption • When Ongoing Checks detect a system error • Beginning EST	Goes into back up ventilator mode (BUV)	Have ventilator serviced; provide alternate ventilation
QUEST or TEST	Press <EST> button (and follow the prompts)	Ventilator displays EST FAIL or EST COMPLETE. Conditional ventilation (that is, ventilator is not operating normally but can be used if institutional protocol permits) begins only when either state is overridden	Have ventilator serviced or override EST COMPLETE
LAMP TEST	Press <LAMP TEST> and <ENTER>	Faulty indicators or displays will not illuminate; audible alarm will not sound	Have faulty indicators, displays, or audible alarm replaced
Ongoing Checks	Routinely during normal operation	If a fault is detected the ventilator goes into VENTILATOR INOPERATIVE (SAFETY VALVE OPEN). If a system error is detected, the ventilator runs POST, opens the safety valve and tries to recover. If it cannot recover, the ventilator goes into BUV. After detection of three system errors, the ventilator goes into BUV	Have ventilator serviced; provide alternate ventilation
I:E Ratio Check	Each time operator changes tidal volume, respiratory rate, peak inspiratory flow, plateau or waveform	Value for parameter is not accepted (the ventilator emits four beeps)	Change tidal volume, peak inspiratory flow, plateau, or respiratory rate, as indicated by prompt
Nebulizer Flow Check	Continuously during nebulization (every eighth breath)	Nebulizer circuit is automatically turned off	Check nebulizer circuit for leaks/disconnect

Alarms

Audible and visual alarms notify the operator when the ventilator:

- operates outside the preset alarm thresholds (HIGH PRESSURE LIMIT, LOW INSPIRATORY PRESSURE, LOW PEEP/CPAP PRESSURE, LOW EXHALED TIDAL (or MINUTE) VOLUMEs, HIGH RESPIRATORY RATE);

NOTE – The LOW PEEP/CPAP PRESSURE alarm may trigger based on a criterion other than the programmed alarm limit (for example, when 5 liters or more of flow is detected in a spontaneous inspiration).

- senses problems with electrical power, source gas, or the patient service system (LOW BATTERY, LOW PRESSURE AIR (or O_2) INLET, EXHALATION VALVE LEAK, power disconnect), and
- requires operator intervention (APNEA, I:E).

The alarm indicators take the form of colored ventilator status displays (VENTILATOR INOPERATIVE, VENTILATOR ALARM, CAUTION, BACK UP VENTILATOR, SAFETY VALVE OPEN, and NORMAL), 12 individual red alarm lights, and an audible alarm.

In general, when an alarm threshold is reached, the ventilator sounds the audible alarm (unless silenced) and flashes the VENTILATOR ALARM display and appropriate indicator(s). When the alarm condition is corrected, the ventilator deactivates the audible alarm and steadily illuminates the CAUTION display and appropriate indicator(s). All alarms in the VENTILATOR STATUS section except the LOW BATTERY and I:E indicators behave in this manner.

The CAUTION display and steady alarm indicator remain lit after the alarm condition is auto-reset to inform the operator that ventilator alarms were activated previously but are no longer active. To clear these displays, the operator must press the <ALARM RESET> key.

When a LOW BATTERY or I:E alarm condition occurs, the ventilator steadily illuminates the corresponding alarm indicator but does not sound the audible alarm or light the ALARM display. Each alarm resets to a NORMAL display status.

Ventilator alarms may or may not affect ventilation. The following alarms do not affect ventilation: LOW EXHALED TIDAL VOL, LOW INSPIRATORY PRESSURE, LOW EXHALED MINUTE VOL, LOW PEEP/CPAP PRESSURE, HIGH RESPIRATORY RATE, APNEA, EXHALATION VALVE LEAK, LOW BATTERY and I:E. (In CPAP only an APNEA alarm triggers initiation of apnea ventilation).

These alarms may affect ventilation: HIGH PRESSURE LIMIT, LOW PRESSURE O_2 INLET, and LOW PRESSURE AIR INLET. The existence of a HIGH PRESSURE LIMIT alarm causes a mandatory inspiration to terminate and initiates exhalation. The LOW PRESSURE AIR (or O_2) INLET alarms prompt the ventilator to switch over to an alternate gas source of adequate pressure or, if there is no alternate source, places the ventilator in a SAFETY VALVE OPEN state.

Power Disconnect Alarm

The power disconnect alarm monitors both the position of the ventilator's power switch and the AC power to the ventilator. If the switch is in the ON position and AC power is not being delivered to the ventilator (for example, due to an accidentally disconnected power cord or a tripped circuit breaker), the audible alarm sounds. The safety valve opens and the patient breaths room air unassisted by the ventilator. When the power switch is moved to the OFF position or when power is restored to the ventilator, the power disconnect alarm ceases. See the Back up Ventilator section in this chapter for information on ventilator function when AC power is low.

Table 2-6 and Table 2-7 list the conditions that trigger and auto-reset the alarms.

Table 2-6. Conditions that Trigger and Auto-reset 12 Individual Alarm Indicators

Alarm	Condition that Triggers It	Condition that Auto-resets It
HIGH PRESSURE LIMIT	Patient circuit peak airway pressure is greater than the set limit	Patient circuit peak airway pressure during next inspiration fell below the set limit
LOW EXHALED TIDAL VOL (disabled if set to 0)	In CMV: Value for the four-breath running average for the mandatory breath is less than the set minimum In SIMV and CPAP: Volume for the four-breath running average for the spontaneous breaths is less than the set minimum	In CMV: Value for the four-breath running average for the mandatory breath is greater than the set minimum In SIMV and CPAP: Volume for the four-breath running average for the spontaneous breaths is greater than the set minimum Disconnect and apnea ventilatio can also reset this alarm
LOW PRESSURE O_2 INLET	Pressure at the oxygen inlet fitting is less than 35 psig and the O_2% setting is 22 or greater	Inlet oxygen pressure is greater than the required amount for at least 3 seconds or O_2 is set to 21% by the operator
LOW INSPIRATORY PRESSURE	Peak airway pressure is less than the set minimum for one complete mandatory breath cycle	Resets at the start of the next mandatory inspiration; to avoid reactivation, peak airway pressure must be greater than the set limit for 0.1 seconds or more
LOW EXHALED MINUTE VOL (disabled if set to 0)	All minute volumes based on an eight-breath projected running total or on a one-minute sample, whichever comes first Sum of minute volume for mandatory and spontaneous breathes is less than the set minimum	Sum of minute volume for mandatory and spontaneous breaths is greater than the set minimum
LOW PRESSURE AIR INLET	Pressure at the air inlet is equal to or less than 35 psig when connected to wall air or when compressor pressure is less than 7.5 psig	Wall air inlet pressure is greater than 35 psig or compressor pressure is greater than 7.5 psig when using the compressor
LOW PEEP/CPAP PRESSURE (disabled if set to 0)	Airway pressure is equal to or less than the set minimum for longer than 1 second or 5 liters delivered in spontaneous breathing	Airway pressure exceeds the set minimum for 1 second, or patient initiates exhalation
HIGH RESPIRATORY RATE (disabled if set at 0)	Breath rate for the 10-breath running average is greater than the set maximum	Breath rate for the 10-breath running average is less than the set maximum

Table 2-6. Conditions that Trigger and Auto-reset 12 Individual Alarm Indicators (continued)

Alarm	Condition that Triggers It	Condition that Auto-resets It
LOW BATTERY	Voltage of the internal batteries is too low to sustain 1 hour of audible alarm and battery-backed memory	Voltage of the internal batteries is sufficient to sustain at least 1 hour of audible alarm and battery-backed memory
APNEA	No exhalation detected during apnea interval	The beginning of the breath after the pneumatic system delivers two successive patient-initiated breaths triggered by the airway pressure reaching the inspiratory threshold. Each breath must return at least 50% of the tidal volume delivered.
I:E	Duration of a mandatory inspiration (including plateau time) is more than 50% of the duration of the complete breath cycle	Duration of a mandatory inspiration (including plateau time) is equal to or less than 50% of the duration of the complete breath cycle
EXHALATION VALVE LEAK	The volume of gas detected through the exhalation flow sensor during an inspiration is greater than 10% of the delivered volume or 50 ml, whichever is greater	The volume of gas through the exhalation flow sensor during an inspiration is less than 10% of the delivered volume or 50 ml, whichever is greater

Table 2-7. Conditions that Trigger Emergency Modes, Warning Messages, and other Alarms

Alarm/Emergency Mode	Condition that Triggers It	Condition that Auto-resets It
Power Disconnect	Power switch is in "ON" position but no AC power is delivered to the ventilator	Does not auto-reset. Must be manually reset by moving the power switch to "off," or by restoring AC power
Disconnect Ventilation	Microprocessor electronics detects inconsistencies between airway pressure, PEEP, and gas delivery pressure in the pneumatic system that indicates the patient service system is disconnected/ plugged	Does not auto-reset. Correct problem and press <ALARM RESET>
Apnea Ventilation	Ventilator detects apnea and no LOW INSPIRATORY PRESSURE alarm exists (unless in CPAP)	Resets in the same manner as the apnea alarm

Emergency Modes of Ventilation

Three emergency modes of ventilation support the patient when the ventilator detects certain problem conditions. These modes are: apnea ventilation, disconnect ventilation, and back up ventilator. The ventilator automatically initiates these modes whenever it detects certain faults or system errors, or whenever certain alarms trigger. During

apnea ventilation and disconnect ventilation, the ventilator continues to operate, using the settings selected by the operator for apnea ventilation. During back up ventilator mode, factory-preset parameters are used.

WARNING – *The PEEP/CPAP control is independent of microprocessor electronics. For this reason, any change in the PEEP/CPAP control setting becomes active immediately during apnea ventilation, back up ventilator, and disconnect ventilation modes. Because the displays may not function properly during these emergency modes, the operator is unable to verify any PEEP setting change and could unknowingly establish a setting which is potentially injurious to the patient. It is recommended that the PEEP setting not be altered during an emergency mode of ventilation, except to turn the knob completely counterclockwise to the zero PEEP level.*

Apnea Ventilation: Apnea ventilation activates whenever apnea is declared (based on the operator-selected apnea interval) and, when operating in CMV or SIMV modes, no LOW INSPIRATORY PRESSURE alarm exists. During apnea ventilation, the ventilator operates with operator-selected settings for apnea tidal volume, apnea respiratory rate, apnea peak inspiratory flow, and apnea O_2 percentage. ALARM illuminates in the alarm summary display and [APNEA VENTILATION] appears in the message window. All keyboard display panel keys are non-operational, except <ALARM SILENCE> and <ALARM RESET>.

After the conditions that caused apnea are corrected, press <ALARM RESET> to restore the ventilator to its pre-alarm state. The patient can cause the ventilator to auto-reset by initiating two consecutive inspirations, each of which returns 50% of the delivered tidal volume. (Normal ventilation begins after the beginning of the third breath following two consecutive breaths.) See Table 3-8 for apnea ventilation parameters.

Disconnect Ventilation: An emergency mode that activates whenever microprocessor electronics detects inconsistencies among airway pressure, PEEP, and the gas delivery pressure in the pneumatic system. These may be caused by disconnected or plugged tubing.

When the ventilator enters disconnect ventilation, the ventilator operates with the tidal volume, respiratory rate, peak inspiratory flow, and oxygen percentage parameters set for apnea ventilation. Sensitivity is not recognized during disconnect ventilation.

During disconnect ventilation, the audible alarm activates (unless silenced), ALARM illuminates in the alarm summary display, the HIGH PRESSURE LIMIT alarm indicator illuminates, and [AIRWAY PRESS DISCONN] appears in the message window. Disconnect ventilation can be detected during both mandatory and spontaneous breathing.

<ALARM RESET> and <ALARM SILENCE> are the only keys which operate during disconnect ventilation. After the condition that causes disconnect ventilation is corrected, press <ALARM RESET> to restore the ventilator to its pre-alarm state. Disconnect ventilation does not auto-reset.

Back Up Ventilator (BUV): An emergency mode that activates whenever POST detects an error or Ongoing Checks detect three sys-

tem errors within 24 hours, or whenever AC voltage falls below 90% of the rated value.

Whenever POST or Ongoing Checks detect a system error in a ventilator, the ventilator runs POST (this automatically activates SAFETY VALVE OPEN). If the ventilator passes POST, it will resume normal operation, but the occurrence of the system error will be stored in battery-backed memory. The third detected system error in a 24-hour period puts the ventilator into BUV.

If the supply voltage drops more than 10% below the nominal rating, microprocessor electronics activate BUV and the audible and visual alarms. The ventilator continues monitoring the voltage supplied and, as long as voltage is below 90%, the ventilator operates in BUV and displays [LOW AC POWER] in the message window. When supply voltage increases to a level 10% or less below the rated value, microprocessor electronics cancels the BUV mode, invokes POST, and restores operation at the current ventilator settings.

In BUV, the pneumatic system is controlled by an analog circuit, separate from microprocessor electronics. The ventilator operates with factory-preset values instead of the operator-selected settings. (These settings are 0.5 liter tidal volume, 12 bpm respiratory rate, 45 Lpm peak inspiratory flow, square waveform, current PEEP setting, and 100% O_2 unless unavailable. High pressure limit is approximately 30 cmH_2O above PEEP. All other settings and functions are disabled or suspended.) When BUV is initiated, BACK UP VENTILATOR illuminates in the alarm summary display and the audible alarm sounds. All other displays blank and all keyboard display panel controls, except the PEEP/CPAP knob, are nonoperational. (Do not raise the PEEP level during BUV because the appropriateness of the setting cannot be verified.)

WARNING – *If BUV activates, the patient should be provided with alternate means of ventilatory support as soon as possible. The ventilator must be serviced before it is used again.*

Safety Valve Open

When a condition occurs preventing the ventilator from implementing an emergency ventilatory mode, the ventilator opens the safety valve. This action causes the patient service circuit to open to room air and the patient breaths room air, unassisted by the ventilator, exhaling against zero PEEP. Check valves prevent any retrograde inspiration or exhalation flows.

The following conditions may trigger the SAFETY VALVE OPEN state:

- air and oxygen supplies have been lost
- a fault has been detected
- power to the ventilator has been disrupted
- POST is in progress

If safety valve open takes effect due to loss of both gas supplies, SAFETY VALVE OPEN illuminates in the alarm summary display, the audible alarm sounds, and [SVO DUE TO LSP] appears in the mes-

sage window. ("SVO" means "safety valve open" and "LSP" means "low supply pressure".)

If the ventilator goes into a safety valve open state because a system fault has been detected, VENTILATOR INOPERATIVE and SAFETY VALVE OPEN illuminate in the alarm summary display, the audible alarm sounds, and an error message appears.

If the supply voltage suddenly drops to zero, the ventilator sounds the audible alarm and opens the safety valve. When supply voltage is restored to normal, the ventilator initiates POST. After successful completion of POST, the ventilator resumes normal operation with the current settings. If the ventilator fails POST, it switches to BUV. The audible alarm remains on, and BACK UP VENTILATOR illuminates on the alarm summary display panel.

The ventilator automatically declares safety valve open during the running of POST. When this occurs, SAFETY VALVE OPEN illuminates in the alarm summary display, but the audible alarm does not sound. Unless one of the above conditions exists, the safety valve open state terminates at the conclusion of POST.

WARNING – *Although a change in PEEP settings during a safety valve open condition has no immediate effect, the change becomes active as soon as the safety valve closes. For this reason, it is recommended that the PEEP setting not be raised while the ventilator is in safety valve open state.*

Gas Supply Switch-Over Circuit

The gas supply switch-over system enables the ventilator to change to a viable gas source if the other sources fail. These types of switchings are possible:

- From wall air to air supplied by the compressor pedestal, when the compressor pedestal is used with the ventilator. This action is independent of microprocessor electronics; it is controlled by a pressure switch.
- From air to oxygen, and from oxygen to air. These actions are normally controlled by pressure switches, which produce signals monitored by microprocessor electronics. If microprocessor electronics fails and BUV is invoked, the circuitry associated with BUV controls the switching logic.

WARNING – *Both oxygen and air (from the wall or compressor pedestal) must be supplied to the ventilator for the gas supply switch-over system to operate effectively. If only one gas source is supplied to the ventilator and that source fails, the switch-over system would operate, but detect no alternate gas source, and the ventilator would switch to safety valve open. The patient would then breathe room air, unassisted by the ventilator.*

For a ventilator equipped with a compressor pedestal, switching to and from the compressor is determined by the pressure of the wall-supplied air. Whenever that pressure falls below 35 psig, the compressor is turned on. No alarm triggers. The compressor automatically turns off and switches out of the air circuit whenever the wall-supplied air is restored to the appropriate pressure.

POST always opens the compressor relief valve, which bleeds the pressure from the compressor's air line while the compressor is restarting. Then, if the ventilator passes POST and begins operation, the valve closes and the compressor resumes providing air flow to the ventilator. This action minimizes the momentary peak current drain required to bring the motor armature up to rated speed.

If the ventilator does not have a compressor and the wall air supply pressure falls below 35 psig, or if compressor pressure falls below 7.5 psig, the air circuit will be closed, the ventilator will switch to 100% oxygen, and the LOW PRESSURE AIR INLET alarm will trigger. For the switch-over to occur, oxygen must be supplied to the ventilator.

If the oxygen supply pressure falls below 35 psig when the operator-selected O_2% parameter is 22% or greater, the oxygen circuit will be closed and the LOW PRESSURE O_2 INLET alarm will trigger. Ventilation will proceed with 100% air.

The gas supply switch-over circuit is functional during BUV, although the LOW PRESSURE O_2 INLET and LOW PRESSURE AIR INLET alarms are not.

Operating Instructions 3

Introduction

This chapter describes how to set up and use the 7200ae Ventilator. It provides procedures for preoperational and postoperational inspection and testing, and operating the ventilator. These instructions are not intended as recommended protocol for clinical use of the ventilator.

Read and become familiar with these instructions before attempting to ventilate a patient.

Preoperational Procedures

CAUTION – Before using the ventilator for the first time, check the following items to prevent serious damage to the ventilator:

- Check that the ventilator has been set up and its accessories have been installed correctly. Refer to Chapter 6 for installation and assembly instructions.
- Check the information on the electrical rating label, located on the ventilator's utility panel and be certain that the AC power is of proper voltage and frequency. Serious damage to the ventilator may result if the AC voltage and frequency supplied to the ventilator do not match those specified on the electrical rating label.
- Be sure that the total electrical load does not exceed the ampere rating of the branch circuit, especially when using the ventilator with the compressor and other medical equipment. (A branch circuit includes all outlets serviced by one circuit breaker.) If the maximum current drain through a branch circuit exceeds its rating, the branch circuit breaker will open, causing the ventilator to lose power. For further information, consult a service technician.

Preoperational Inspection Points

Before turning on the ventilator, inspect it for operational readiness. Repeat this inspection before every use. The following procedures are labeled by step number in Figures 3-1 through 3-3.

WARNING – *To prevent serious injury, never cut or remove the grounding prong or attempt to defeat the grounding feature.*

1. Is the unit plugged in? Connect the power cord (Figure 3-1) directly into a properly grounded three-wire receptacle.
2. Is the flex arm positioned correctly (Figure 3-2)?

WARNING – *Do not use a patient service circuit containing an external exhalation valve. Such a valve could cause increased expiratory resistance or occlusion, or inhibit the ventilator's ability to sense the patient's inspiratory effort.*

3. Are all connections for the patient service system tight (Figure 3-2)? Are in-line water traps empty (if any)?

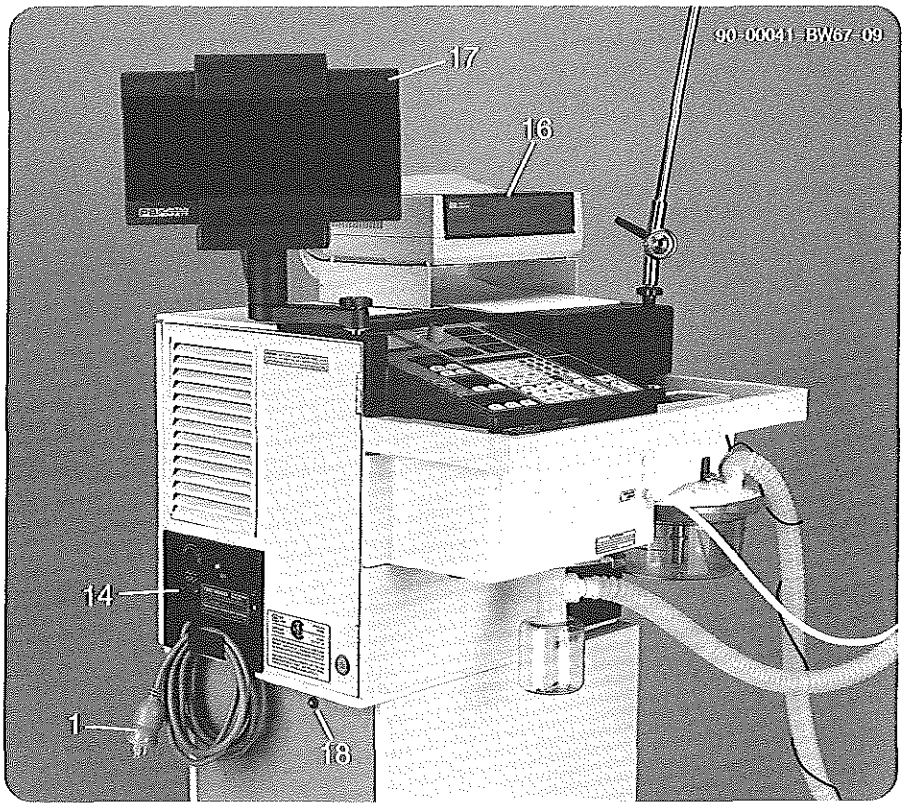


Figure 3-1. Inspection Points — Various Electrical Connections

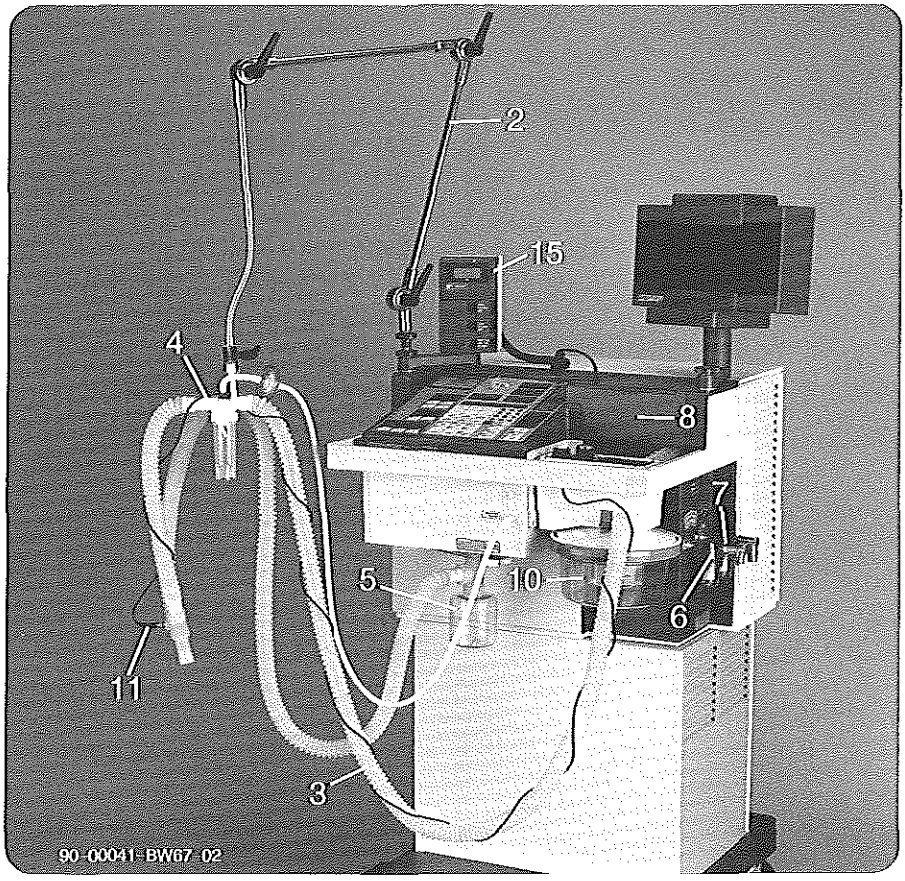


Figure 3-2. Inspection Points — Simplified Patient Service Circuit

4. Is the nebulizer vial (if installed) in place and tight? If not installed, cap the nebulizer connection on the ventilator (Figure 3-2).

CAUTION – Always supply gas to the nebulizer by way of the ventilator. Do not use a separate gas source.

5. Is the exhalation collector vial (Figure 3-2) free of condensate? Drain the vial if necessary.
6. Are the gas supply water traps and filters (Figure 3-2) cleaned and any condensate drained? (See Chapter 4 for cleaning instructions.)

NOTE – The air and oxygen water traps and their filters should be replaced every 2500 hours as part of preventive maintenance.

7. Are oxygen and air inlet connections secure (Figure 3-2)?

WARNING – *The exhalation bacteria filter must be unobstructed for proper operation and patient safety. Check the heated exhalation bacteria and main flow bacteria filters daily.*

8. Have the main flow and heated exhalation bacteria filters been checked? For disposable filters, monitor ventilator performance and replace as needed. For reusable filters, measure resistance as described in Chapter 4. After the ventilator has been running for approximately 15 minutes, check the function of the filter heater by verifying that it is warm to the touch.
9. In the exhalation compartment (Figure 3-3), is the filter clamp locked securely over the clamp catch? Push the filter clamp into place, if necessary.

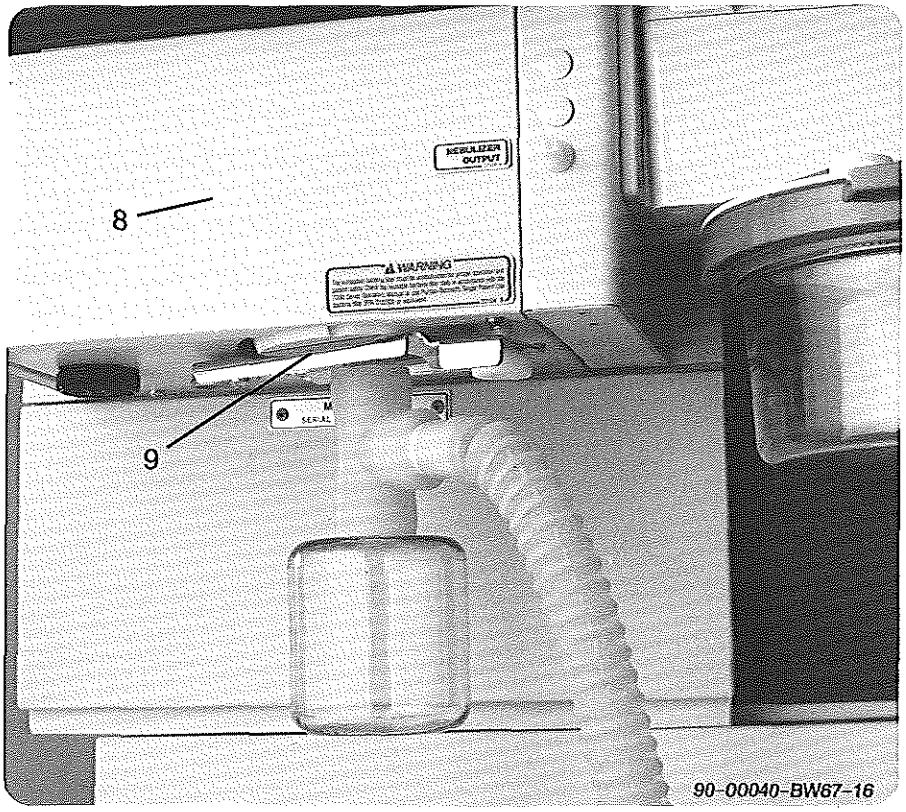


Figure 3-3. Inspection Points – Exhalation Compartment

10. Check the humidifier (Figure 3-2). Is it turned on? Are connections secure? Is the water level (if applicable) within operating limits? (In this example, the Cascade II Humidifier is shown. For other humidifiers, see the humidifier's operator's manual for specific instructions.)
11. Is an airway temperature probe connected (Figure 3-2)? (If the humidifier is not equipped with one, use a Puritan-Bennett P/N 4-007900-00 temperature alarm to monitor airway temperature.)
12. Have all appropriate parts been cleaned and sterilized? Perform any recommended periodic maintenance, as described in Chapter 4.
13. Has Extended Self-Test (EST) been run recently? Perform Quick EST (QUEST) every time the ventilator is used and every time the circuit is changed. Perform Total EST (TEST) periodically as part of preventative maintenance. (Refer to Chapter 5 for how to run EST.)

The following inspection steps apply to optional equipment. Refer to the product literature for additional information.

14. If applicable, is the remote nurse's call and the recording device for pressure and flow connected to the output signal connector (Figure 3-1)?
15. If using an O_2 monitor (Figure 3-2), is it properly mounted? Is it turned on and its sensor connected? Has it been calibrated?

NOTE - Puritan-Bennett recommends the periodic use of an O_2 monitor to verify oxygen mix.

16. If using a printer (Figure 3-1), is it properly mounted on the ventilator and correctly configured? If not, refer to the printer installation instructions. Is the cable properly attached? Is the printer turned on? Does it have an adequate supply of paper and ink? Is the paper positioned at the top of the form?
17. If using the 7202 Display (Figure 3-1), is it securely mounted on the ventilator? Is the connector securely inserted in the back of the ventilator? If it does not work, refer to the *7202 Display* appendix.
18. If the ventilator has a compressor (Figure 3-1), is the compressor operational? Press the reset button and check the electrical outlet if the compressor circuit breaker has tripped.

Preoperational Testing

Before using the ventilator, perform the following diagnostic tests. Turn on the ventilator with the power switch, located on the utility panel (Figure 3-4).

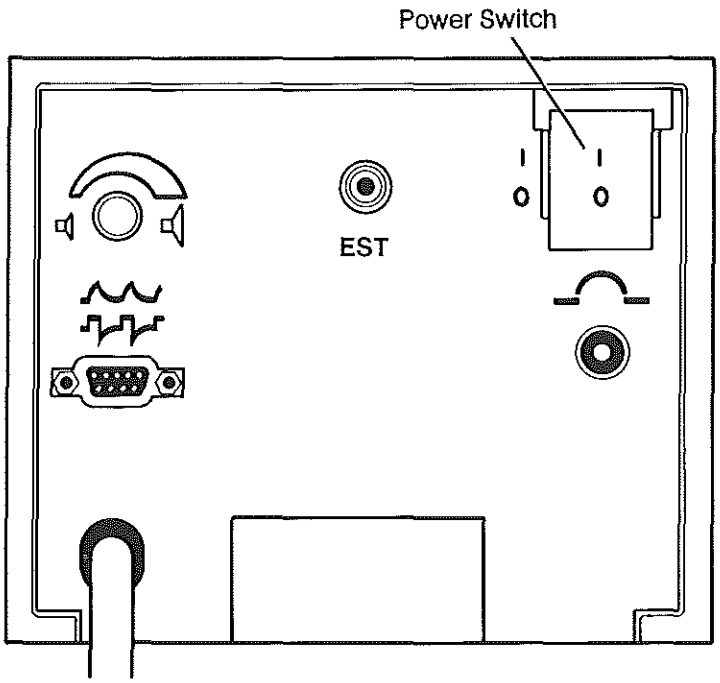


Figure 3-4. Utility Panel

Power-On Self-Test (POST)

When the power switch is turned on, the ventilator automatically initiates a 5-second electronic validation test called Power-On Self-Test (POST). POST also runs when power to the ventilator is momentarily interrupted or when the Extended Self-Test is initiated.

During POST, the message [POWER-ON SELF-TEST] appears in the message window (Figure 3-5) and the SAFETY VALVE OPEN display illuminates. When the ventilator passes POST, it begins operating with all settings, indicators, and displays as they were before POST.

The message window displays [REVIEW APNEA PARAMS] as a reminder to verify the appropriateness of the current apnea ventilation parameters. Review the parameters for the current patient because values from previous use, which are stored in battery-backed memory, may be inappropriate. (See the section Selecting <++> Key Function 1 – Apnea Ventilation Parameters in this chapter to set apnea ventilation parameters.)

If the ventilator does not pass POST, BACK UP VENTILATOR illuminates, the audible alarm sounds, and the ventilator operates with preset parameters. The message [WXYZ ERR] appears, where WXYZ represents an error code. If you turn ventilator power on then off, [RUN EST–DO NOT USE] appears; have the ventilator serviced before using. If the ventilator fails POST after a power loss and a patient is still connected, replace the ventilator as soon as possible.

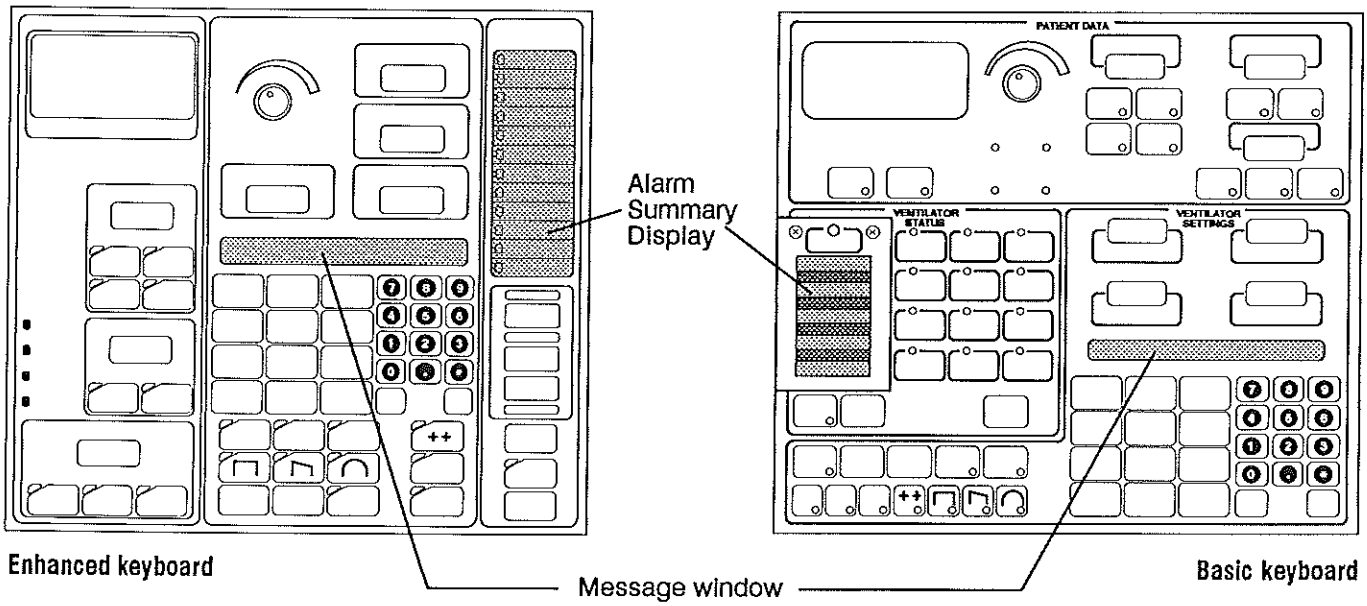


Figure 3-5. Location of Messages and Displays During POST

NOTE – A battery change may cause an error message to be temporarily displayed in the message window. The message disappears by the time POST is successfully completed and the ventilator then operates normally.

Quick Extended Self-Test (QUEST)

Quick Extended Self-Test (QUEST) calculates the patient circuit compliance and the exhalation valve's area ratio, checks the patient service system for leaks, and verifies battery-backed memory. QUEST lasts approximately 1.5 minutes. Perform QUEST every time the ventilator is used and every time the circuit is changed. See Chapter 5 for how to run QUEST. (Perform Total Extended Self-Test (TEST) as part of periodic ventilator maintenance.)

Lamp Test

Lamp test is a 40-second test that checks all displays, meters, and lamps on the keyboard display panel, as well as the audible alarm and the analog OUTPUT SIGNAL connector. At the beginning of lamp test, the software revision level is displayed.

Perform lamp test as part of preoperational testing and whenever you suspect a problem in the keyboard display panel:

- Initiate by pressing the <LAMP TEST> key followed by <ENTER> (Figure 3-6).
- After lamp test runs once, it begins again, repeating the test sequences. When this second pass finishes, lamp test ends.
- To cancel lamp test, press any key on the keyboard display panel.

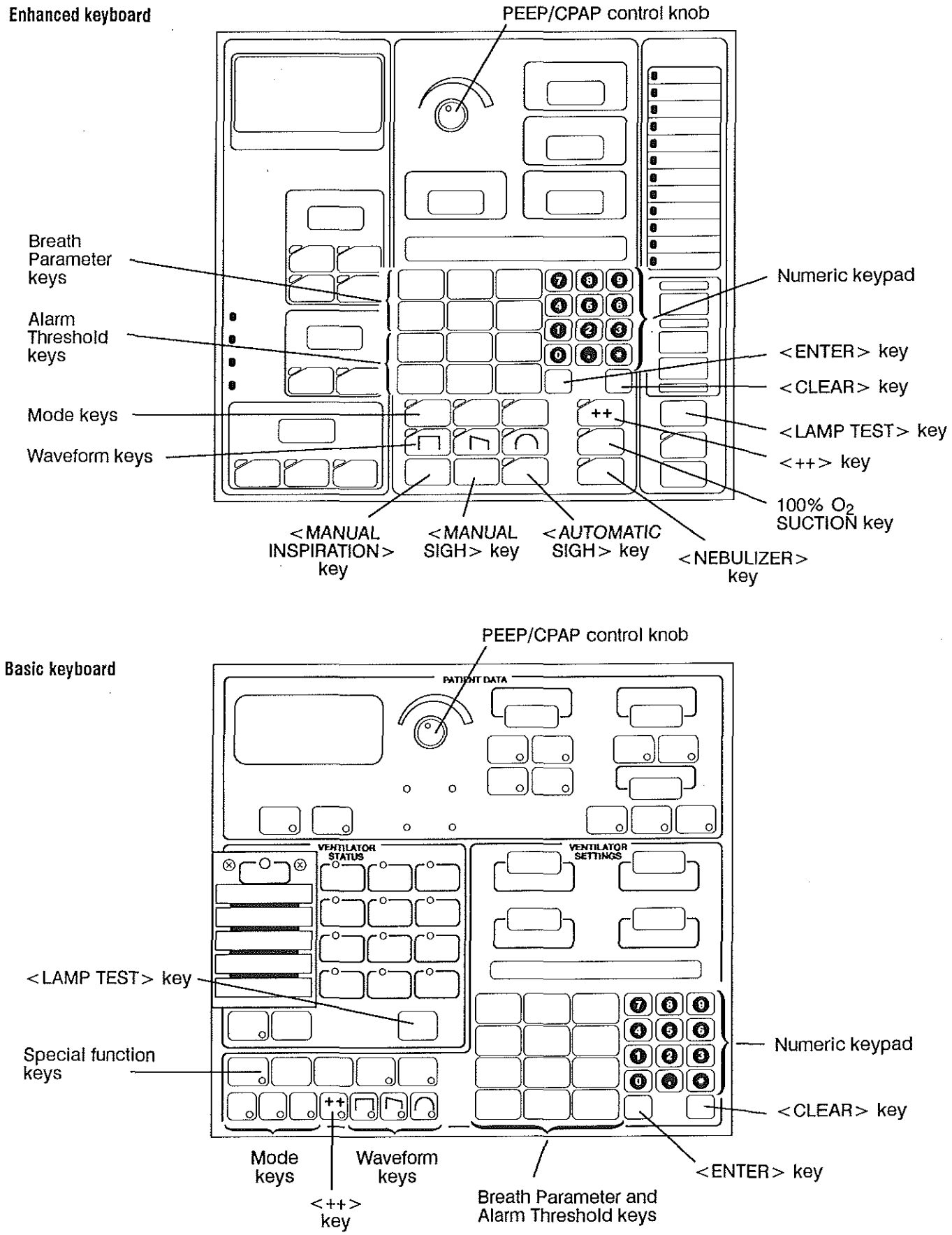


Figure 3-6. Location of <LAMP TEST> Key and Ventilator Settings Keys

In addition, lamp test automatically cancels under the following emergency or alarm conditions:

- Power disconnect
- Apnea ventilation
- Disconnect ventilation
- Back up ventilation
- Safety valve open
- Nebulizer disconnect

NOTE - During lamp test, ventilator displays may not be accurate. However, monitoring and alarm detection continues, and the audible alarm remains functional. To ensure that you notice alarm conditions during lamp test, <ALARM SILENCE> is canceled if it is selected. Press any key to cancel lamp test if the alarm sounds.

Operating the Ventilator

Selecting Ventilator Settings

After inspection, self-tests, and correction of identified problems, the ventilator is ready to use on a patient. First select the settings to ventilate the patient. Choose most ventilator settings with keys and knob in the blue (or blue-bordered) VENTILATOR SETTINGS section of the keyboard display panel. (With the Basic keyboard, set the PEEP/CPAP level with the knob in the green-bordered PATIENT DATA section.) See Figure 3-6 for the locations of the keys and knob.

Using its batteries, the ventilator is able to retain operator-selected settings, even after ventilator power is turned off. However, whenever the batteries are removed or replaced, settings revert to default values, shown in Table 3-1.

Selection of modes, waveforms, breath parameters, alarm thresholds, and optional functions is discussed in the following paragraphs. Table 3-9 at the end of this chapter summarizes how to select ventilator functions using the ventilator settings keys. Detailed instructions for each key group appear in the following paragraphs.

When selecting ventilator settings, first review apnea ventilation and automatic sigh parameters to ensure that these are appropriate for the patient. See Selecting <++> Key Functions in this chapter for how to review and change these parameters.

Table 3-1. Default Settings

Parameter/Threshold	Default Setting
Mode	CMV
Waveform	Square
Tidal Volume (and apnea ventilation tidal volume)	0.5 L
Respiratory Rate (and apnea ventilation respiratory rate)	12 bpm
Peak Inspiratory Flow(and apnea ventilation peak flow)	45 Lpm
Sensitivity	3 cmH_2O
O_2% (and apnea ventilation O_2%)	100%
Plateau	0 seconds
100% O_2 Suction	Off
Automatic Sigh	Off
Sigh Tidal Volume	0.0 ml
Sigh High Pressure Limit	40 cmH_2O
Multiple Sighs per Sigh Event	1
Sigh Events per Hour	1
Nebulizer	Off
Apnea Interval	20 seconds
High Pressure Limit alarm	20 cmH_2O
Low Inspiratory Pressure alarm	3 cmH_2O
Low PEEP/CPAP Pressure alarm	0 (disabled)
Low Exhaled Tidal Volume alarm	0 (disabled)
Low Exhaled Minute Volume alarm	0 (disabled)
High Respiratory Rate alarm	0 (disabled)

Modes

The ventilator offers three modes for patient ventilation that can be modified and expanded when options are installed and activated.

- The Continuous Mandatory Ventilation (CMV) mode provides mandatory breaths only. These breaths may be initiated by the ventilator, the patient, or the operator (using <MANUAL SIGH> or <MANUAL INSPIRATION>). The SENSITIVITY setting determines the amount of patient effort to trigger an assist breath.
- In the Synchronous Intermittent Mandatory Ventilation (SIMV) mode, breathing may be both mandatory and spontaneous, with mandatory breaths initiated by the operator (<MANUAL INSPIRATION> or <MANUAL SIGH>), the patient, or the ventilator.
- In the Continuous Positive Airway Pressure (CPAP) mode, spontaneous breaths and patient-initiated sigh breaths are delivered. As in other modes, operator-initiated breaths are available with <MANUAL INSPIRATION> or <MANUAL SIGH>.

To select a mode, press the appropriate key (Figure 3-7), then <ENTER>. The ventilator beeps twice and the indicator on the mode key lights when the choice is accepted. When changing modes, review all breath parameters and alarm thresholds, and change them if necessary.

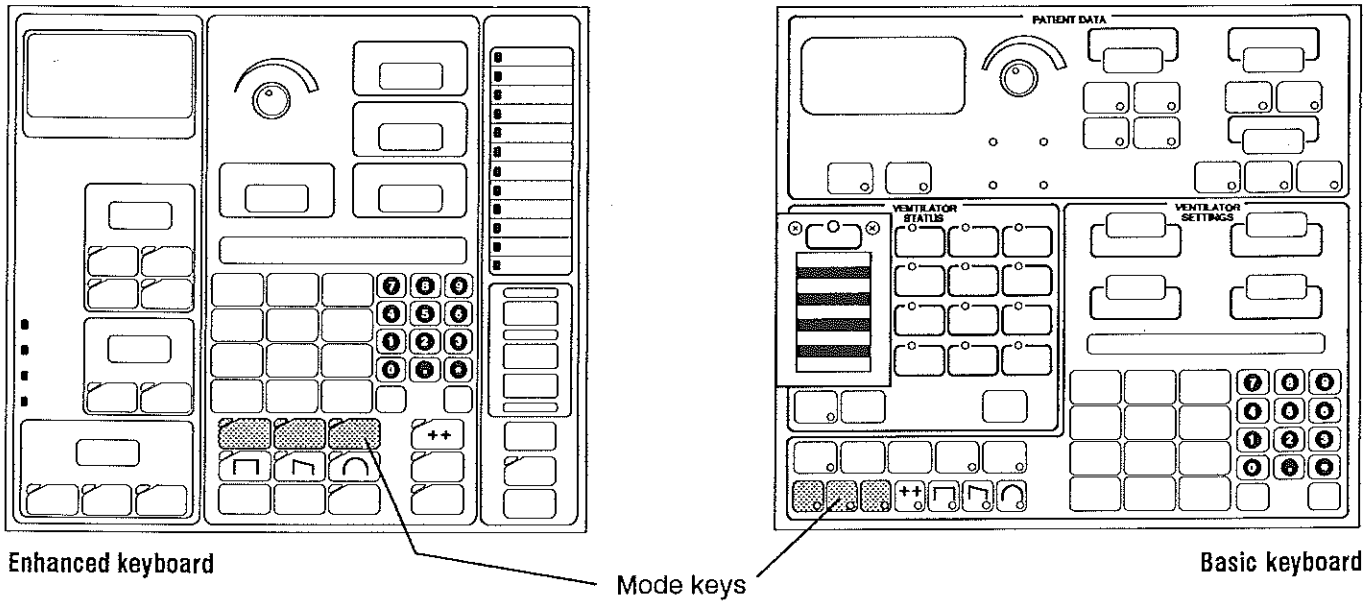


Figure 3-7. Mode Keys

Waveforms

Choose one of three waveforms to define mandatory breaths (square wave, descending ramp, and sine wave). To select a waveform, press the waveform key (Figure 3-8), then <ENTER>. The ventilator beeps twice and the key's indicator lights when the choice is accepted.

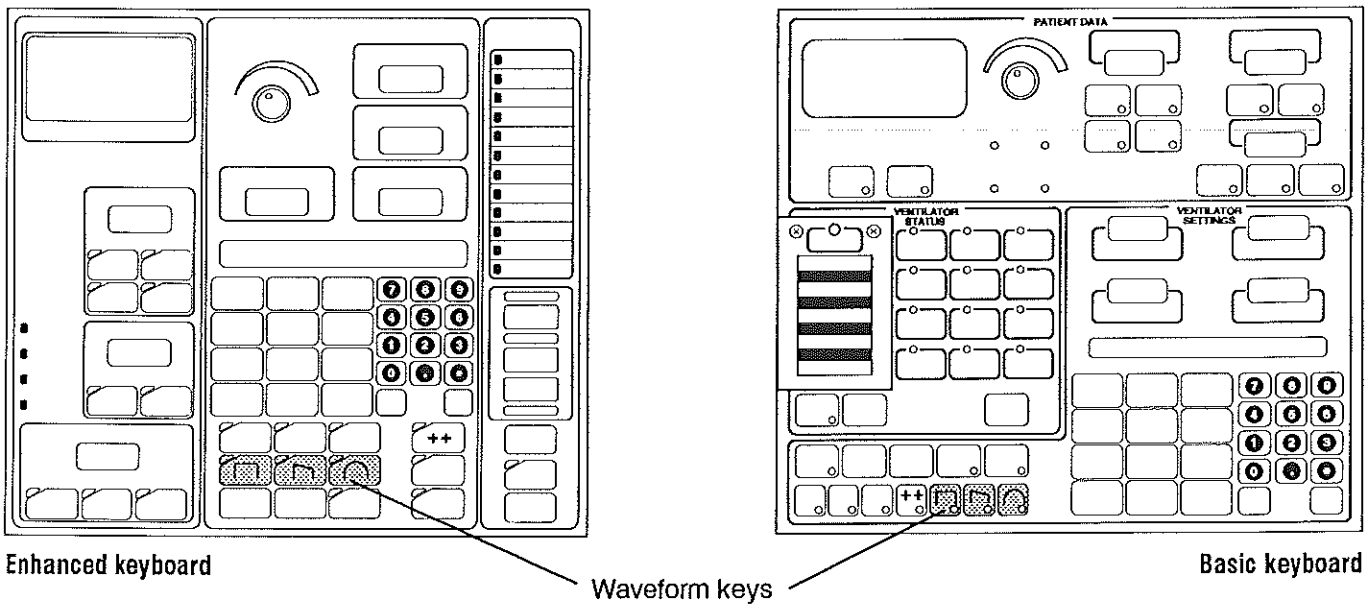


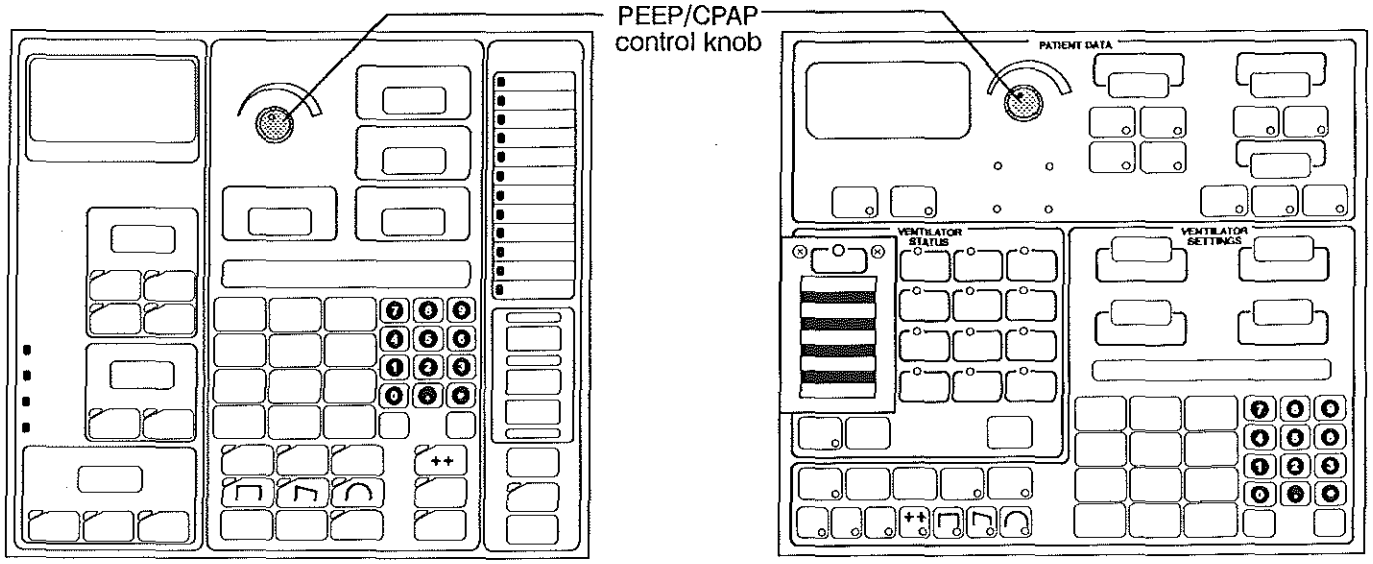
Figure 3-8. Waveform Keys

PEEP/CPAP Level

Use the PEEP/CPAP knob (Figure 3-9) to set the PEEP level. Turn the knob clockwise to raise PEEP and counterclockwise to lower it. The *digital PEEP value, shown in the cmH_2O window, is the set target value* that the ventilator attempts to acheive; the analog meter displays actual PEEP in the airway. Use the analog meter for fine-tuning PEEP levels as long as the needle is sufficiently stable during end expiration. If the analog PEEP value is unstable, due to patient inspiratory efforts, the digital value can be used. Use the analog meter when setting PEEP below 3 cmH_2O.

The digital PEEP value may not match the analog value because of two situations. Current patient settings may be causing inadvertent PEEP (for example, the patient is prevented from fully exhaling). Or, the digital display may be compromised by an inappropriate area ratio calculated during the last EST. In this case, run QUEST to recalculate an accurate area ratio.

WARNING *- The PEEP/CPAP control knob is independent of microprocessor electronics. So, any change to PEEP becomes active immediately during apnea ventilation, back up ventilator, and disconnect ventilation modes. Because the displays may not function properly during these emergency modes, you may be unable to verify a PEEP change and could unknowingly establish an injurious PEEP level. Do not alter the PEEP level during an emergency mode of ventilation, except to turn the knob completely counterclockwise to zero.*



Enhanced keyboard

Basic keyboard

Figure 3-9. PEEP/CPAP Control Knob

Breath Parameters and Alarm Thresholds

Review breath parameters and alarm thresholds whenever a mode change is made.

Use the 12 labeled keys and the numeric keypad in the VENTILATOR SETTINGS section (Figure 3-10) to set breath parameters and alarm thresholds. The ventilator does not accept a new value unless it is within the permissible range and <ENTER> is pressed.

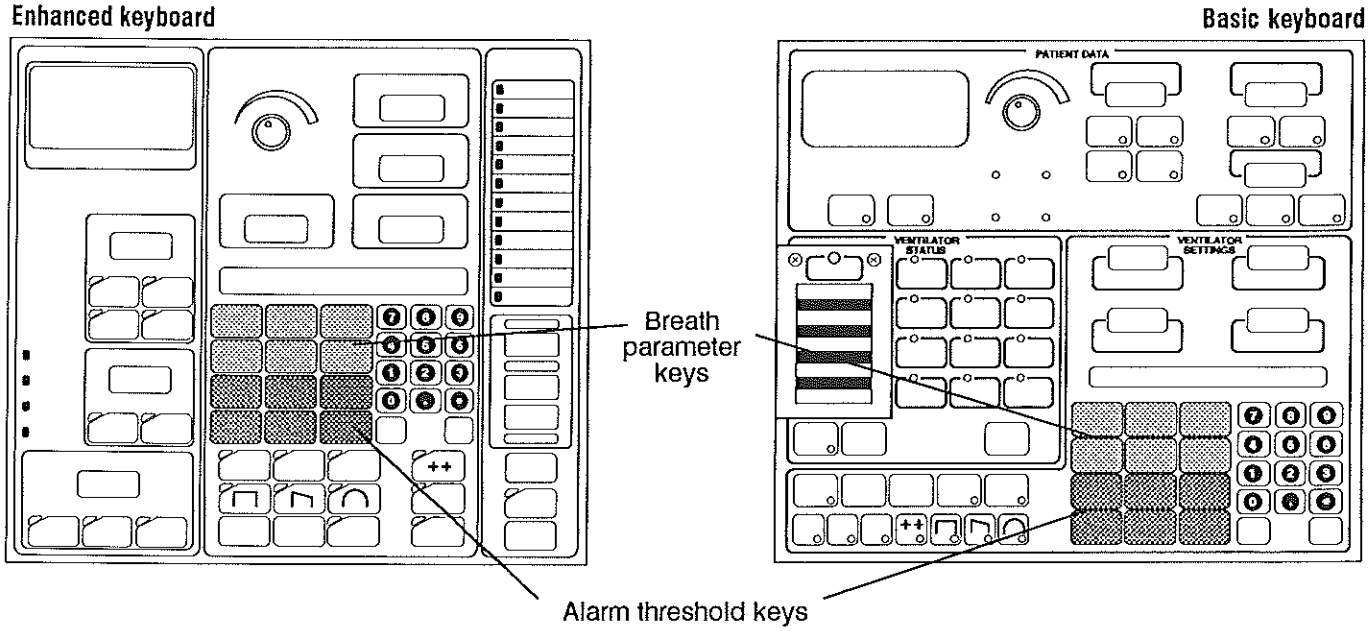


Figure 3-10. Breath Parameter and Alarm Threshold Keys

To specify a value for a breath parameter or alarm threshold, do the following (Figure 3-11 shows the entry sequence in flowchart form):

1. Press the key for the desired function. The current value appears in the message window.
2. If you want to retain the current value, press <ENTER> or another parameter key, or wait 18 seconds until the message changes or times out. The ventilator continues operating with the existing setting.
3. If you want another value, do the following:
   - Key in the new value with the numeric keypad. Or, press <CLEAR> to erase the value in the message window and key in a new value.
   - Verify that the new value is the one desired; if so, press <ENTER>. Unless the setting is out of range or causes another error message, the ventilator beeps twice and accepts the change. (See the Error Messages section in this chapter and Table 3-3.) The new value takes effect on the next breath cycle, except for sensitivity, which usually takes effect immediately.

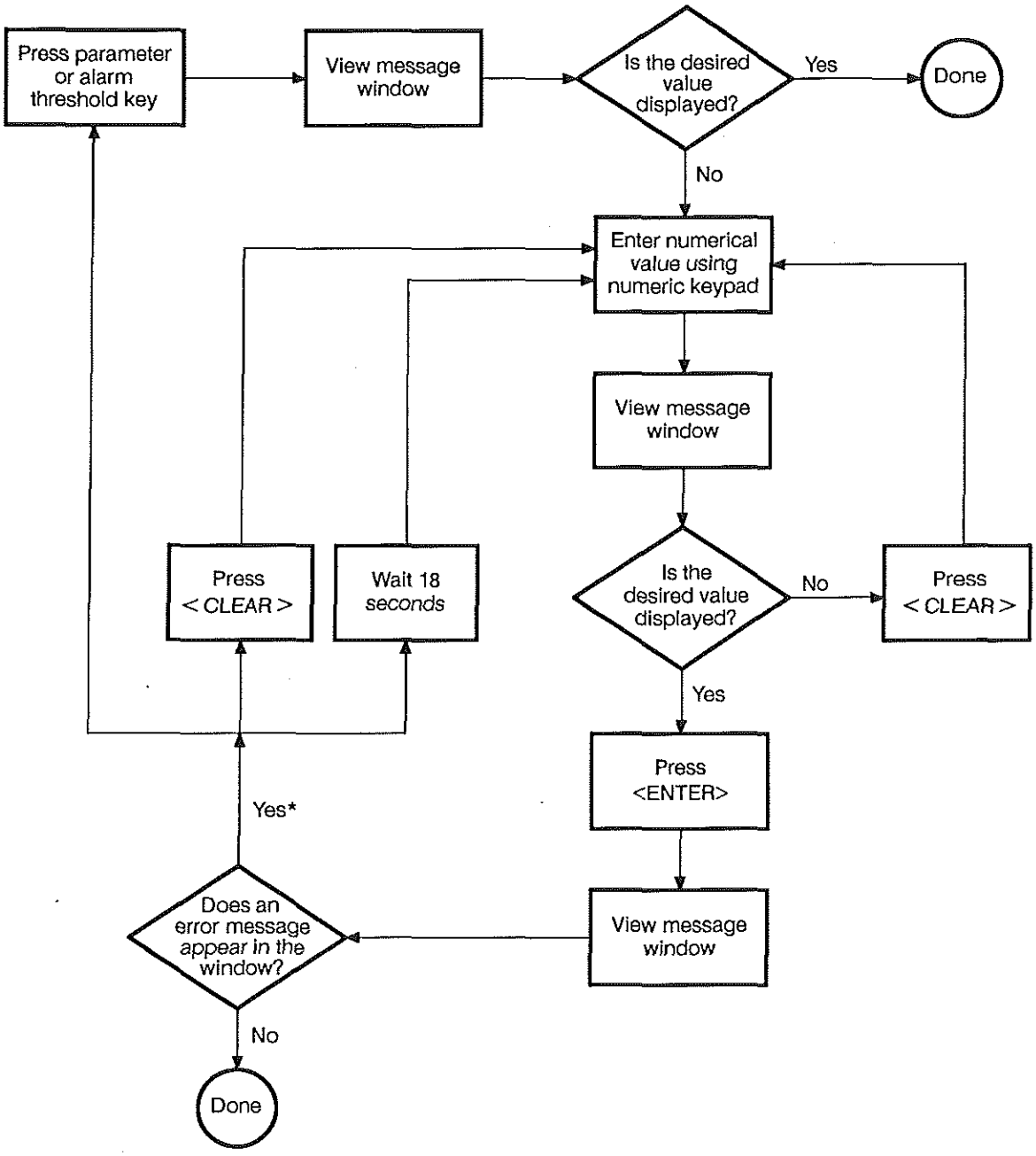
Decimals are keyed in using the decimal point (<.>) key. If the desired value is less than 1.00, it is not necessary to key in the leading zero.

The Low Inspiratory Pressure alarm threshold and Tidal Volume, Respiratory Rate, Peak Inspiratory Flow, Plateau, and Waveform breath parameters apply only to mandatory breaths. Since mandatory breaths are available in all modes, select appropriate values for these functions, even when the patient is expected to breathe spontaneously.

Tidal Volume, Respiratory Rate, Peak Inspiratory Flow, and O_2% have digital displays in the VENTILATOR SETTINGS section of the keyboard. When these settings are changed, the displays flash the old set-

tings until the new settings take effect. The displays also flash when delivered parameters differ from the operator-selected parameters (as occurs during apnea ventilation, disconnect ventilation, delivery of 100% O_2 for suctioning, and safety valve open conditions.) During CPAP, the respiratory rate display is blanked.

Parameters are set differently for apnea ventilation and automatic sigh, as described later in this chapter.



* See Table 3-3 (Error Messages during Breath Parameter and Alarm Threshold Selection) for which specific action to take.

Figure 3-11. Parameter/Threshold Entry Sequence Flowchart

Permissible Ranges for Ventilator Settings

Breath parameters and alarm thresholds can only be changed to values within specific ranges, which are listed in Table 3-2. If you enter a parameter or threshold that is outside the range, error messages appear and the ventilator retains the current setting until an acceptable entry is made.

Although the ventilator allows entry of additional decimal places, the ventilator only recognizes a specific amount. The Smallest Increment column in Table 3-2 lists those amounts.

Table 3-2. Permissible Ranges for Breath Parameters and Alarm Thresholds

Parameter or Alarm Threshold	Range	Smallest Increment	Comments
Tidal Volume	0.10 to 2.50 liters	0.01 liter	
Respiratory Rate	0.5 to 9.9 bpm 10 to 70 bpm	0.1 bpm 1.0 bpm	Can cause an immediate breath if the new cycle interval is less than the time elapsed since the inspiration began.
Peak Inspiratory Flow	10 to 120 Lpm	1 Lpm	Maximum flow of 180 Lpm for a spontaneous breath when wall air and oxygen are supplied.
Sensitivity	0.5 to 20.0 cmH_2O	0.1 cmH_2O	This number, subtracted from digital PEEP, determines the inspiratory threshold required for the patient to trigger inspiration.
O_2%	21 to 100%	1%	Selecting 21% disables the LOW PRESSURE O_2 INLET alarm unless no air is available. If O_2% is set to 21% after this alarm is activated, the alarm shuts off.
Plateau	0.0 to 2.0 seconds	0.1 second	Delivered during mandatory breaths or sighs only.
High Pressure Limit	10 to 120 cmH_2O	1 cmH_2O	This alarm cannot be defeated by entering 0.
Low Inspiratory Pressure	3 to 99 cmH_2O	1 cmH_2O	This alarm cannot be defeated by entering 0.
Low PEEP/CPAP Pressure	0 to 45 cmH_2O	1 cmH_2O	Selecting 0 disables the alarm. If the alarm is already active, entering 0 turns it off at the end of the next breath.
Low Exhaled Tidal Volume	0.00 to 2.50 liters	0.01 liter	Selecting 0 disables the alarm. If the alarm is already active, entering 0 turns it off at the end of the next breath.

Table 3-2. Permissible Ranges for Breath Parameters and Alarm Thresholds (continued)

Parameter or Alarm Threshold	Range	Smallest Increment	Comments
Low Exhaled Minute Volume	0.0 to 60.0 liters	0.1 liter	Selecting 0 disables the alarm. If the alarm is already active, entering 0 turns it off at the end of the next breath.
High Respiratory Rate	0 to 70 bpm	1 bpm	Selecting 0 disables the alarm. If the alarm is already active, entering 0 turns it off at the end of the next breath.
Sigh Parameters.			
Sigh Tidal Volume	0.0, 0.10 to 2.50 liters	0.01 liter	This value may not be greater than twice the tidal volume for non-sigh breaths or less than the non-sigh tidal volume. A zero setting turns sigh off and disables the manual sigh function.
Sigh High Pressure Limit	10 to 120 cmH_2O	1 cmH_2O	This value may not be less than the limit for non-sigh breaths.
Sigh Events Per Hour	1 to 15	1	Corresponds to a sigh every 4 to 60 minutes.
Number of Sighs Per Sigh Event	1 to 3	1	This value sets the number of consecutive sighs.
Apnea Ventilation Parameters			
Apnea Interval	10 to 60 seconds	1 second	Default: 20 seconds
Apnea Tidal Volume	0.10 to 2.50 liters	0.01 liter	Default: 0.5 liter
Apnea Respiratory Rate	0.5 to 9.9 bpm 10 to70 bpm	0.1 bpm 1.0 bpm	Default: 12 bpm
Apnea Peak Flow	10 to 120 Lpm	1 Lpm	Default: 45 Lpm
Apnea O_2	21 to 100%	1%	Default: 100% O_2

Error Messages During Breath Parameter/Alarm Threshold Selection

If a breath parameter or alarm threshold is outside the permissible range or if a parameter is within range but causes the I:E ratio check to fail, the ventilator beeps four times and displays an error message. Table 3-3 lists some of those messages.

Table 3-3. Error Messages During Breath Parameter and Alarm Threshold Selection

Error Message	Meaning	Operator Action
[INVALID ENTRY]	Value is out of range.	Press <CLEAR>. The name of the parameter or alarm threshold and the units of measure reappear in the message window. Key in a new value and press <ENTER>, *or* Press the parameter or alarm threshold key. The name of the parameter or alarm threshold and the current value will appear in the message window. Key in a new value and press <ENTER>, *or* Wait 18 seconds. [INVALID ENTRY] will cancel automatically and the name of the parameter or alarm threshold and the current value will appear in the message window. Key in a new value and press <ENTER>.
[DECR RESP RATE FIRST]	Decrease respiratory rate first. Value is in range but causes the I:E ratio check to fail.	This message appears when a new value is selected for tidal volume, peak inspiratory flow, plateau, or waveform which causes the length of inspiratory phase to equal or exceed 75% of the length of mandatory breath cycle interval (I:E displayed as 1:0.3), as determined by the I:E ratio check. In this case, the ventilator gives preference to the length of the inspiratory phase; therefore, you must lengthen the cycle interval (as defined by the <RESPIRATORY RATE>) to cause the I:E ratio check to pass. Decrease <RESPIRATORY RATE> to increase the total cycle interval and eliminate this conflict.
[CHANGE PK F/TV FIRST]	Change peak flow or tidal volume first.	This message appears whenever a change in respiratory rate would cause the length of the inspiratory phase to equal or exceed 75% of the mandatory breath cycle interval (I:E displayed as 1:0.3), as determined by the I:E ratio check. In this case, the ventilator gives preference to the length of the cycle interval; therefore, you must shorten the duration of breath delivery to cause the I:E ratio check to pass. Increase peak inspiratory flow, change waveform, decrease tidal volume, or reduce plateau period to decrease the length of the inspiratory phase and eliminate this conflict.

Selecting Manual Inspiration

This function causes the ventilator to deliver a mandatory breath according to current breath parameters. It lasts for one inspiration only. Press the <MANUAL INSPIRATION> key and a breath is delivered immediately (unless a mandatory breath is already in progress). (See Figure 3-12 for where the key is located.)

Selecting Manual Sigh

This function delivers a sigh breath according to sigh parameters entered via the <AUTOMATIC SIGH> key. A manual sigh lasts for one sigh inspiration only.

Press the <MANUAL SIGH> key and a sigh breath is delivered immediately, unless a mandatory breath is in progress. If sigh parameters have not been set via <AUTOMATIC SIGH>, no sigh breath is delivered and [REVIEW SIGH PARAMS] appears in the message window. (See Figure 3-12 for where the key is located.)

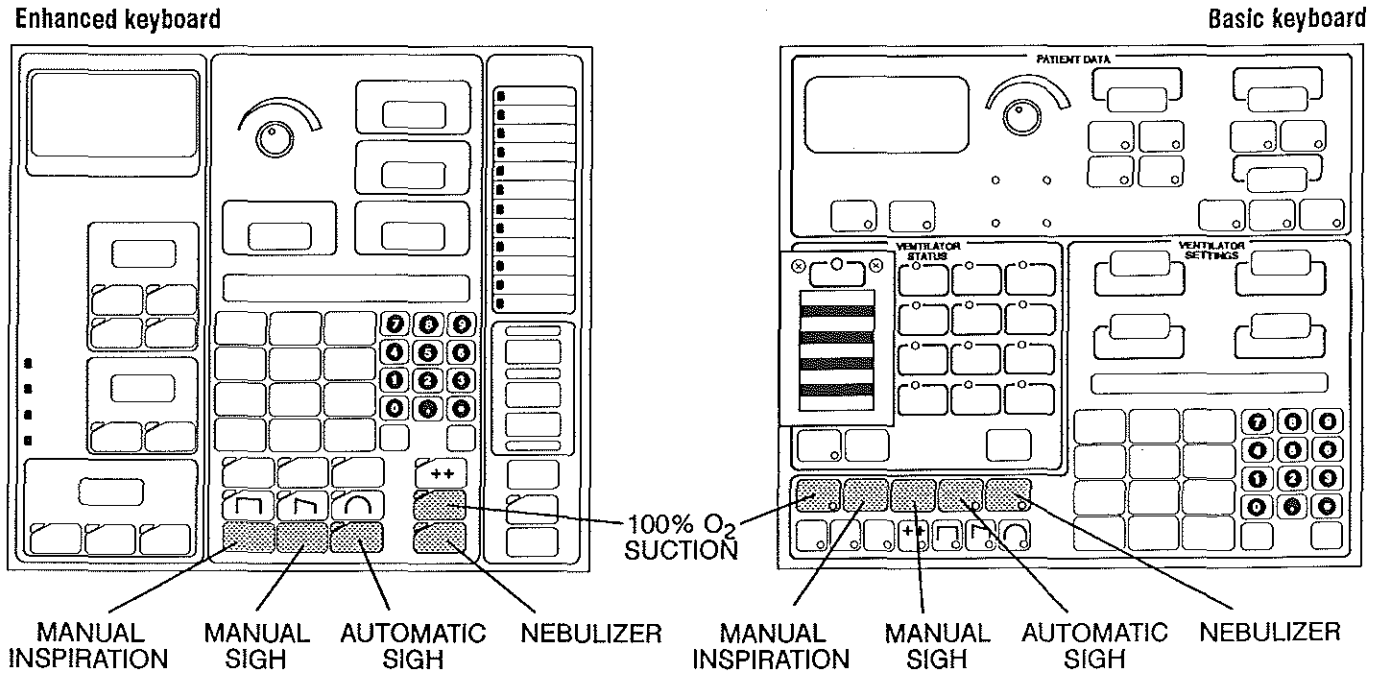


Figure 3-12. Special Function Keys

Selecting Automatic Sigh

This function causes the ventilator to automatically deliver sigh breaths *as specified. To turn on the function, press the* <AUTOMATIC SIGH> key, and the following prompts appear (X represents a value):

[SIGH TV X.XX LITERS]
[SIGH HIPL XXX CMH20]
[SIGH RATE XX PER HR]
[MULTIPLE X SIGHS]
[UPDATE PARAMS – ENTER]
[AUTO SIGH ON – ENTER]

The prompt [AUTO SIGH OFF – ENTER] may appear first if automatic sigh is already on. Press <CLEAR> to leave automatic sigh on. Parameter values are entered as described in Table 3-9 at the end of this chapter.

To step through automatic sigh parameters without making changes, press <ENTER> after each parameter message appears in

the window. To scroll backwards through the parameters, press the <* > key.

The ventilator checks sigh parameters to ensure that sigh tidal volume and sigh high pressure limits are compatible with the parameters for non-sigh ventilation. If settings are unacceptable, as defined in Table 3-2, the following error messages may appear:

Error Message	Meaning
[ENTRY LESS THAN TV]	Sigh tidal volume cannot be less than normal tidal volume.
[ENTRY EXCEEDS 2XTV]	Sigh tidal volume cannot be greater than twice the normal tidal volume.
[ENTRY LESS THAN HIPL	Sigh high pressure limit cannot be less than normal high pressure limit.
[INVALID ENTRY]	The entered value is out of permissible range.

In addition, if tidal volume is raised above sigh tidal volume, the sigh volume is raised to match the new tidal volume. If tidal volume is lowered to less than one-half the sigh tidal volume, the sigh value is set to 2 times the new tidal volume. If high pressure limit is raised above the sigh high pressure limit, the sigh limit is raised to match the new limit.

A sigh extends the breath cycle interval for twice the normal cycle interval, unless terminated earlier by expiration of the apnea interval. In SIMV, when three breath cycles have elapsed since the sigh breath and the patient has not initiated a breath, the patient receives one ventilator-initiated mandatory breath. In this interval, <MANUAL INSPIRATION> and <MANUAL SIGH> are active.

NOTE - If the ventilator loses AC power immediately following an automatic sigh event, a sigh breath is delivered after power is restored and POST is successfully completed.

To cancel automatic sigh, press <AUTOMATIC SIGH> and press <ENTER> when the prompt [AUTO SIGH OFF–ENTER] appears.

Selecting 100% O_2 Suction

This feature causes the ventilator to deliver 100% O_2 (if O_2 is available) for 2 minutes before patient suctioning. When O_2% is set to other than 100, the value in the O_2 % window flashes to indicate that it differs from the operator-selected value. After 100% O_2 is turned off or is automatically canceled, the ventilator reverts to the original value.

Press the <100% O_2 SUCTION> key (Figure 3-12) and <ENTER> to turn on the function. The indicator on the key illuminates and sounds two beep tones as the function is turned on.

Because ventilator alarms are designed to warn about patient or circuit disconnect conditions, they are activated when the patient is disconnected for suctioning. Press <ALARM SILENCE> to cancel the audible alarm during suctioning. After suctioning, press <ALARM RESET> to clear any alarms that occurred during disconnection and verify that the patient circuit is properly reconnected, without kinks or occlusions.

Selecting Nebulizer

Nebulization lasts 30 minutes unless canceled by the operator, or disconnected or suspended by the ventilator. The Flow-by option turns off the nebulizer. Nebulization occurs during inspiration, excluding any plateau period. The nebulizer will not activate when selected if flow to the patient is less than 10 Lpm.

> ***WARNING*** - *The nebulizer requires 10 Lpm of flow to ensure reliable operation. Therefore, the ventilator discontinues flow to the nebulizer if you select, or the patient spontaneously breathes, any combination of peak inspiratory flow and oxygen percentage yielding less than 10 Lpm through the nebulizer circuit. (However, the key's indicator light remains illuminated.) Nebulization resumes when flow reaches an acceptable level.*

The ventilator checks nebulizer flow every eight breaths. Excessive nebulizer flow causes the nebulizer circuit to shut off; [NEB DISCONNECT] appears in the message window. Excessive flow may be caused by leaks or disconnects in the nebulizer tubing.

The nebulizer feature is suspended during apnea and disconnect ventilation and the Respiratory Mechanics/Monitoring option. The nebulizer is also suspended during low pressure oxygen inlet or low pressure air inlet alarms when source gas pressure falls below the minimum operating level (35 psig for wall gas, 7.5 psig for the compressor). When nebulization is suspended, the key's light goes out, the key does not function, the 30-minute timer continues to run, and there is no nebulizer flow. When the situation is corrected, nebulization resumes.

Selecting <++> Key Functions

The <++> key (Figure 3-13) allows you to select some standard functions and to access options (which may be ordered to expand the capabilities of the ventilator). Function 1 (apnea ventilation parameters) and 2 (clock reset) are standard functions. All others are optional.

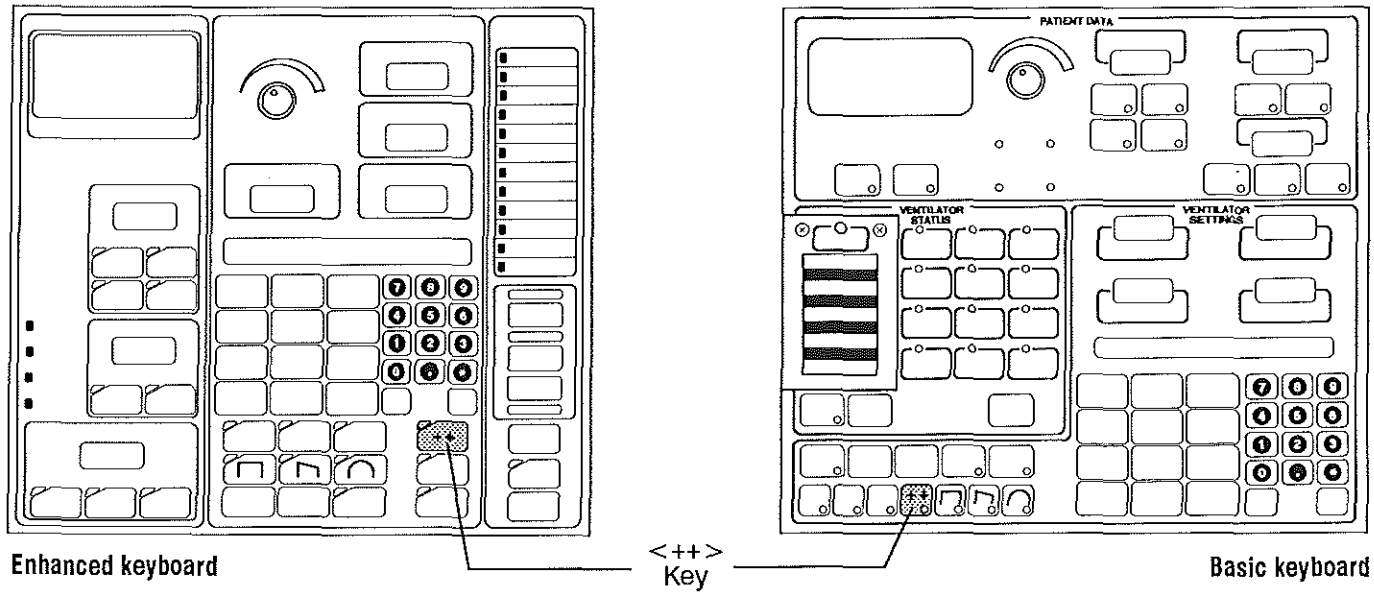


Figure 3-13. <++> Key

To select a <++> key function (such as apnea ventilation parameters), press the <++> key. The last <++> key function selected appears in the message window ([FUNCTION XX SELECT], where X is the number of the function). To select the desired number, press the <++> key to advance, or the <*> key to reverse. The desired function may be accessed more directly by keying in the function number and pressing the <ENTER> key.

In general, activating a <++> key function involves specifying parameters or responding to message window prompts. Once a <++> key function is accessed, the entry sequence may be suspended at any time by the following:

- Allowing the 18-second timeout period to elapse
- Pressing a VENTILATOR SETTINGS key
- Occurrence of an alarm or emergency condition indicated in the message window

Figure 3-14 illustrates the entry sequence for <++> key functions 1 and 2.

Procedures for using optional <++> key functions are provided with the applicable option.

Selecting <++> Key Function 1 Apnea Ventilation Parameters

You may select the monitoring interval for apnea detection as well as the tidal volume, respiratory rate, peak inspiratory flow, and O_2% to be used during apnea ventilation. Refer to the Emergency Modes of Ventilation section in this chapter for how apnea ventilation is invoked.

Apnea ventilation parameters also apply for disconnect ventilation. Some 7200 Series options (e.g. Pressure Control Ventilation) may have separate apnea ventilation parameters. See the appropriate appendix for details.

WARNING – *It is important to review the current settings for apnea parameters every time the ventilator is turned on. The prompt [REVIEW APNEA PARAMS] reminds you to verify that the present parameters are appropriate for the patient.*

Set the apnea interval based on what you, the practitioner, consider to be an unsafe period for the patient to go between breaths. Note that if the apnea interval exceeds twice the SIMV cycle, the ventilator may not detect apnea because ventilator breaths would be delivered before the apnea interval passes.

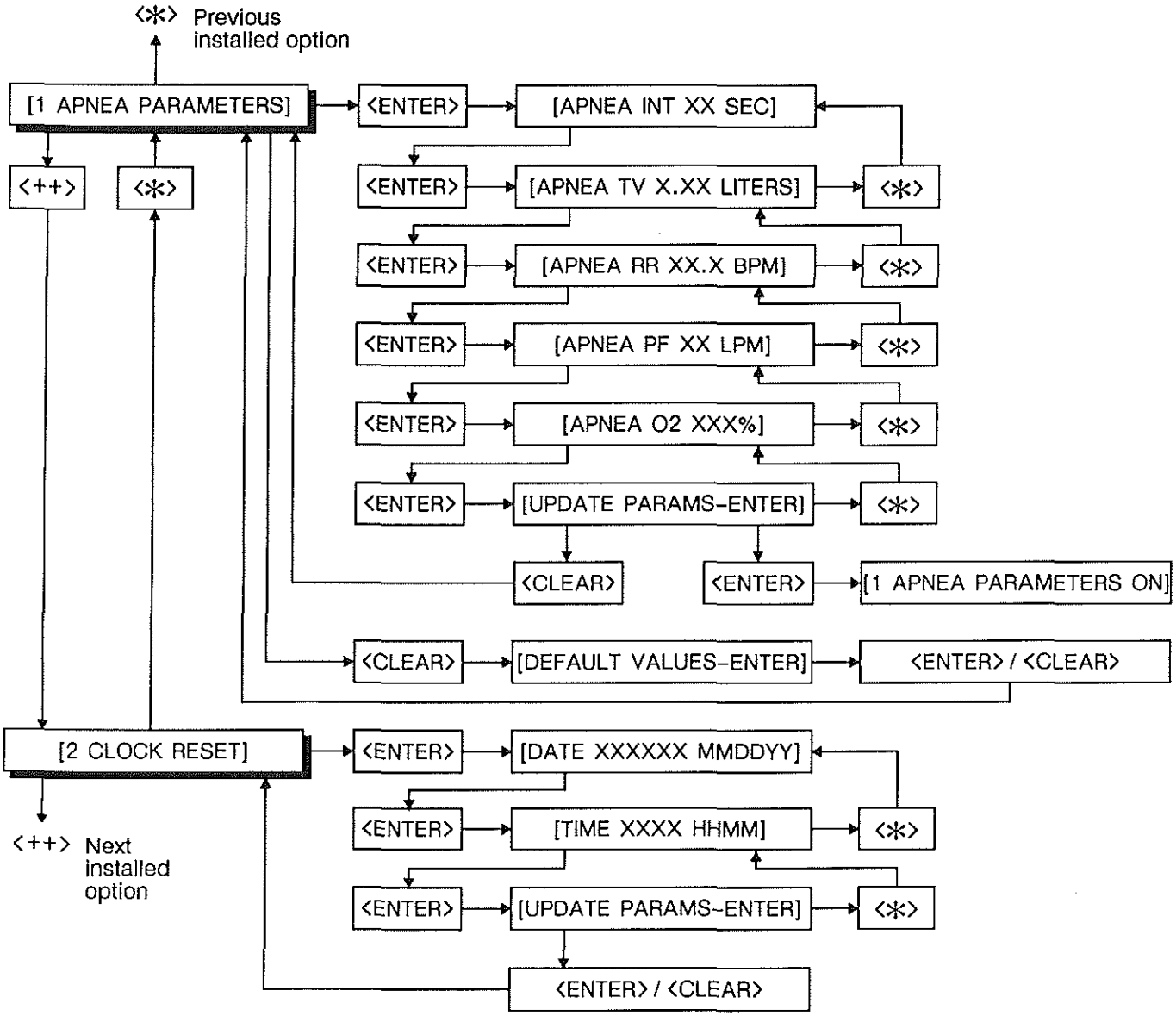


Figure 3-14. Entry Sequence for Standard <++> Key Functions

Table 3-4 explains selection of apnea ventilation parameters. Press <ENTER> to scroll through the parameter prompts. Press <*> to scroll backwards. Press <CLEAR> to blank the parameter value displayed in the window. Unless you press <ENTER> at the [UPDATE PARAMS-ENTER] prompt, the new values will not be used when apnea ventilation is invoked.

I:E ratio checks are made for apnea respiratory rate, tidal volume, and peak inspiratory flow. Therefore, if an entry violates the checking criteria, an error message appears. Refer to Table 3-3 for possible error messages and actions.

Table 3-4. Apnea Ventilation <++> Key Sequence

Operator Action	Message Window Response	Comments
Select option 1.	[1 APNEA PARAMETERS]	To select default values, press <CLEAR>. To select other parameter values, press <ENTER>.
Press <CLEAR>, *or* Press <ENTER>.	[DEFAULT VALUES-ENTER] [APNEA INT XX SEC]	To select default values (Table 3-2), press <ENTER>. XX represents the monitoring interval for apnea detection.
Key in desired value and press <ENTER>, or let current value stand. Press <ENTER>.	[APNEA TV X.XX LITERS]	X.XX represents the apnea tidal volume.
Key in desired value and press <ENTER>, or let current value stand. Press <ENTER>.	[APNEA RR XX.X BPM]	XX.X represents the apnea respiratory rate.
Key in desired value and press <ENTER>, or let current value stand. Press <ENTER>.	[APNEA PF XX LPM]	XX represents the apnea peak inspiratory flow.
Key in desired value and press <ENTER>, or let current value stand. Press <ENTER>.	[APNEA O_2 XXX %]	XXX represents the apnea oxygen percentage.
Key in desired value and press <ENTER>, or let current value stand. Press <ENTER>.	[UPDATE PARAMS-ENTER]	Press <ENTER> for the ventilator to accept the new apnea para-meters. Press <CLEAR> to cancel the new values.
Press <ENTER>.	[1 APNEA PARAMETER ON]	This message confirms that the new apnea parameters have been accepted.

Selecting <++> Key Function 2

Clock-Calendar Reset

The ventilator is designed to maintain the correct date and time. However, you can change the date and time by resetting the clock-calendar. Because the clock-calendar is battery-backed, it must also be reset if battery-backed memory is lost (due to battery replacement, for example).

The term MMDDYY shown in the message window during function 2 indicates month, day, and year. MM represents month (01 to 12), DD represents day (01 to 31), and YY represents year (00 to 99). The expression HHMM indicates the time. HH stands for hours (00 to 23), and MM for minutes (00 to 59).

The ventilator allows you to enter invalid dates and times such as 999999 or 9999. However, these invalid dates and times will not be printed or displayed. The term JAN 01 19XX (19XX is the current ventilator value for year) appears in place of the invalid date and 12:00 for the invalid time.

When the clock-calendar reset function has been selected, key in values for the date and/or the time fields. After each field has been reviewed, the ventilator displays [UPDATE PARAMS-ENTER]. Press <ENTER> within 18 seconds or the ventilator will ignore the changes and continue operating with current date and time.

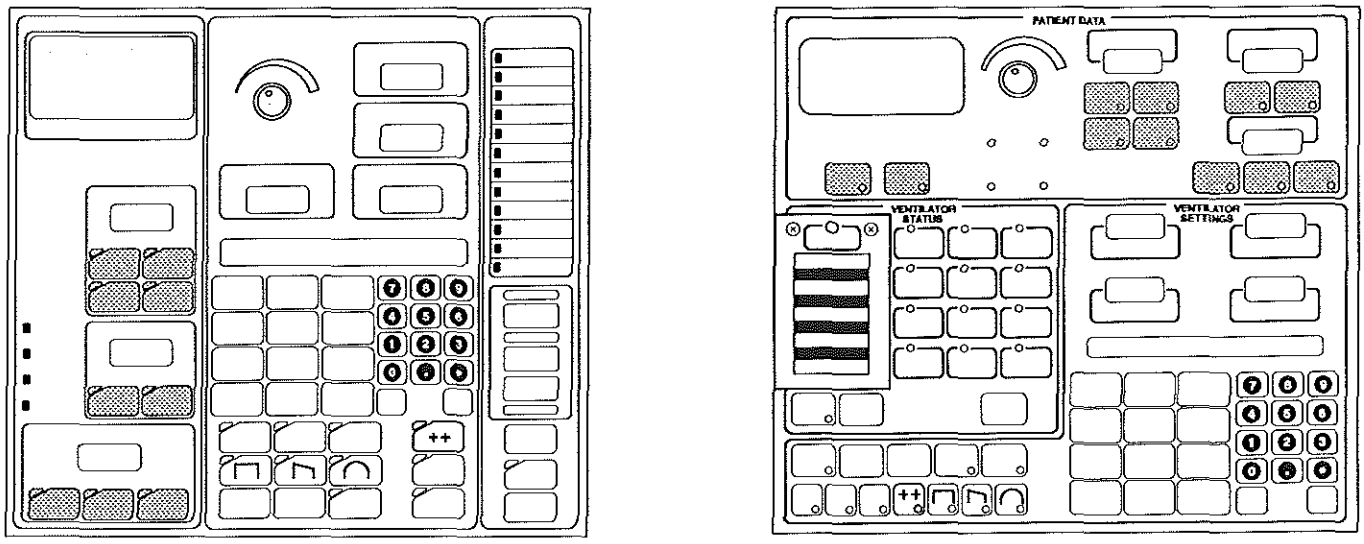
The <CLEAR> key erases the value in the date or time field, one character at a time, from right to left. Press <ENTER> to step through the fields. Press the <✻> key to scroll backward. The following messages appear during clock-calendar reset:

[DATE XXXXXX MMDDYY]
[TIME XXXX HHMM]
[UPDATE PARAMS-ENTER]

Selecting and Monitoring Patient Data Displays

The PATIENT DATAsection of the keyboard display panel includes information on breath types, pressures, volumes, rate, and I:E ratio (Figure 3-15). Each digital display can be used for more than one type of data.

To select a patient data display, choose the data to be shown and press the appropriate key. One beep tone sounds, the key's light illuminates, and the display or meter shifts to the requested data.



Enhanced keyboard

Basic keyboard

Figure 3-15. Patient Data Keys

The PATIENT DATA section contains the following displays and indicators:

- The analog meter, showing airway pressure (in cmH_2O). (On the Standard keyboard, exhaled volume (in liters) can also be shown on the analog meter.)
- The cmH_2O digital display, showing mean airway pressure, peak airway pressure, PEEP/CPAP, or plateau pressure.
- The RATE/I:E digital display, showing rate (in breaths per minute) or the I:E (inspiratory to expiratory time) ratio.
- The liters digital display, showing tidal volume, minute volume, or spontaneous minute volume.
- Breath type indicators: ASSIST, SPONTANEOUS, SIGH, and PLATEAU. They light automatically during assist, spontaneous, sigh, or plateau breaths. No operator activation is required.

  All digital displays are blank during POST.

The displays for mean airway pressure, respiratory rate, tidal volume, minute volume, and spontaneous minute volume are updated at the end of each cycle interval. The display for peak airway pressure is only updated at the end of inspiration of a mandatory breath. The display for the I:E ratio is only updated at the end of a mandatory breath. The plateau pressure display is updated at the end of each plateau period. The analog meter and PEEP/CPAP display are updated continuously during the cycle interval.

The exhaled volume indicated by the analog meter on the Basic keyboard shows total exhaled volume. This value may not match the TIDAL VOLUME value in the liters digital display because the TIDAL VOLUME value is corrected for BTPS and patient tubing compliance.

In the Basic keyboard, the PATIENT DATA section also includes the PEEP/CPAP control knob. This control is described in the PEEP/CPAP Level section in this chapter.

Monitoring Ventilator Status

Alarms and Ventilator-Initiated Emergency Modes

The ventilator continually monitors patient-ventilator performance. With an audible tone, nurse's call, alarm summary display, and 12 specific alarm indicators, the ventilator notifies the operator of detected operational problems. Six of the 12 alarms are triggered at operator-selected thresholds:

- HIGH PRESSURE LIMIT
- LOW INSPIRATORY PRESSURE
- LOW PEEP/CPAP PRESSURE
- LOW EXHALED TIDAL VOLUME
- LOW EXHALED MINUTE VOLUME
- HIGH RESPIRATORY RATE

The remaining six alarms activate under certain set conditions:

- I:E
- APNEA
- LOW PRESSURE O_2 INLET
- LOW PRESSURE AIR INLET
- EXHALATION VALVE LEAK
- LOW BATTERY

Table 3-5 explains the alarm summary display, which provides general information on ventilator operating conditions.

Table 3-5. Function of the Alarm Summary Display

Display	Function
VENTILATOR INOPERATIVE	Red display. When lit, the microprocessor has determined that the ventilator is not functional due to a system fault. Coincides with illumination of SAFETY VALVE OPEN display. Back up ventilation is not provided. (See Chapter 2 for details.)
VENTILATOR ALARM	Red display. Signals that an alarm has been triggered and has not auto-reset. Usually, one or more of 12 indicators flashes to identify it.
CAUTION	Yellow display. Signals that an alarm was activated and automatically reset. Steady illumination of one or more of the 12 indicators identifies the alarm that was active.
BACK UP VENTILATOR	Red display. Lights when the BACK UP VENTILATOR (BUV) emergency mode is active. When the ventilator is in BUV, factory-preset breath parameters are used. See Table 3-8 for the values used.
SAFETY VALVE OPEN	Red display. When lit, the patient circuit is opened to room air and the patient breathes unassisted by the ventilator. The ventilator enters this mode when all connected gas supplies are lost, POST is running, a system fault is detected, or AC power is lost. SAFETY VALVE OPEN is employed temporarily during POST and is canceled after POST is completed successfully.
NORMAL	Green (or blue) display. When lit, the ventilator is operating within acceptable ranges and no alarm conditions exist. If an alarm is reset with the <ALARM RESET> key, this display lights instead of the CAUTION display.

Table 3-6 describes how the specific alarms behave.

Table 3-6. Action of Individual Alarms

Type of Alarm	Alarm State	Effect on Ventilation	Auto-Reset State
HIGH PRESSURE LIMIT	Audible alarm on, flashing ALARM display, flashing HIGH PRESSURE LIMIT indicator.	Terminates mandatory breath delivery; may indicate airway disconnect in message window.	Audible alarm off, steady CAUTION display, steady HIGH PRESSURE LIMIT indicator.
LOW INSPIRATORY PRESSURE	Audible alarm on, flashing ALARM display, flashing LOW INSPIRATORY PRESSURE indicator.	None. In CMV or SIMV, apnea ventilation does not occur until the LOW INSPIRATORY PRESSURE alarm is reset.	Audible alarm off, steady CAUTION display, steady LOW INSPIRATORY PRESSURE indicator.
LOW PEEP/CPAP PRESSURE	Audible alarm on, flashing ALARM display, flashing LOW PEEP/CPAP PRESSURE indicator.	None.	Audible alarm off, steady CAUTION display, steady LOW PEEP/CPAP PRESSURE indicator.
LOW EXHALED TIDAL VOLUME	Audible alarm on, flashing ALARM display, flashing LOW EXHALED TIDAL VOL indicator.	None.	Audible alarm off, steady CAUTION display, steady LOW EXHALED TIDAL VOL indicator.
LOW EXHALED MINUTE VOLUME	Audible alarm on, flashing ALARM display, flashing LOW EXHALED MINUTE VOL indicator.	None.	Audible alarm off, steady CAUTION display, steady LOW EXHALED MINUTE VOL indicator.
HIGH RESPIRATORY RATE	Audible alarm on, flashing ALARM display, flashing HIGH RESPIRATORY RATE indicator.	None.	Audible alarm off, steady CAUTION display, steady HIGH RESPIRATORY RATE indicator.
I:E	Steady I:E indicator.	None.	Indicator off.
APNEA	Audible alarm on, flashing ALARM display, flashing APNEA indicator.	Initiates apnea ventilation (if no active LOW INSPIRATORY PRESSURE alarm in CMV or SIMV); indicates apnea ventilation in message window.	Audible alarm off, steady CAUTION display, steady APNEA indicator.
LOW PRESSURE O_2 INLET	Audible alarm on, flashing ALARM display, flashing LOW PRESSURE O_2 INLET indicator.	Causes ventilator to switch over to air, if available; if air is unavailable, to SAFETY VALVE OPEN (patient breathes room air); suspends nebulization, if on.	Audible alarm off, steady CAUTION display, steady LOW PRESSURE O_2 INLET indicator.
LOW PRESSURE AIR INLET	Audible alarm on, flashing ALARM display, flashing LOW PRESSURE AIR INLET indicator.	Causes ventilator to switch over to O_2, if available; if not, to SAFETY VALVE OPEN (patient breathes room air); suspends nebulization, if on.	Audible alarm off, steady CAUTION display, steady LOW PRESSURE AIR INLET indicator.

Table 3-6. Action of Individual Alarms (continued)

Type of Alarm	Alarm State	Effect on Ventilation	Auto-Reset State
EXHALATION VALVE LEAK	Audible alarm on, flashing ALARM display, flashing EXHALATION VALVE LEAK indicator.	Could cause inadequate patient ventilation since inspiratory gas is leaking past the exhalation valve.	Audible alarm off, steady CAUTION display, steady EXHALATION VALVE LEAK indicator.
LOW BATTERY	Steady LOW BATTERY indicator.	When power is lost, loss of battery-backed memory causes ventilator to operate with default settings.	Indicator off.
Power *Disconnect*	Audible alarm on.	Causes ventilator to switch to SAFETY VALVE OPEN (patient breathes room air).	Audible alarm off.

Responding to Alarm Indicators

When an alarm is triggered:

- Review the status of the patient
- Determine which alarm sounded
- Determine why it sounded
- Take corrective action
- Review other alarms which have automatically reset to the CAUTION state

The alarm will trigger repeatedly if offending conditions are not corrected.

To reset the alarms associated with the alarm indicators, press <ALARM RESET>. Pressing <ALARM RESET> cancels all ALARM and CAUTION states. If the condition that triggered the alarm persists after the <ALARM RESET> key has been pressed, that alarm soon retriggers. If <ALARM RESET> is pressed while either the LOW EXHALED TIDAL VOLUME, LOW EXHALED MINUTE VOLUME or HIGH RESPIRATORY RATE alarm is active, volume calculations are restarted.

The <ALARM SILENCE> key causes the ventilator to suppress the audible alarm and nurse's call for two minutes. After that time, the audible alarm resumes unless the key is pressed again. To cancel alarm silence, press <ALARM RESET>. When <ALARM SILENCE> is pressed before the end of the 2-minute period, the 2-minute timer is reset, and alarm silence begins anew. Pressing <ALARM SILENCE> multiple times does not give multiple 2-minute silence periods.

Visual monitoring of the patient and ventilator is important during the alarm silence period to ensure alarms do not go undetected.

It is important to check the batteries when LOW BATTERY illuminates. The batteries provide power to sound the audible alarm when no AC power is available. They also save ventilator settings and error messages in memory. (However, the batteries do not provide power to operate the ventilator if AC power is lost.)

WARNING *- If LOW BATTERY illuminates, perform a battery check and take appropriate action. (See Chapter 4 for how to run a battery check.) Provide alternate ventilatory support for the patient before attempting to charge or replace batteries. Internal batteries are critical for the proper operation of the ventilator during and afte a disruption of power. Without adequately charged batteries, the ventilator reverts to ventilation using default parameters after a disruption of power and may not automatically resume operation with previous settings.*

Power Disconnect Alarm

When ventilator power is disconnected, the audible alarm sounds, the safety valve opens, and the patient breathes room air unassisted by the ventilator. Due to power loss, there are no visual displays or messages. The audible alarm is sustained by batteries. Cancel the alarm by turning the power switch off. Restoring power and turning on the ventilator cause the ventilator to initiate POST before it resumes normal ventilation.

WARNING *- The nurse's call relay from the output signal connector does not signal loss of power. Patients on life-support equipment should be visually monitored by competent medical personnel, since life-threatening circumstances may arise that might not activate alarms.*

Safety Valve Open

In SAFETY VALVE OPEN (SVO), all parameter, threshold, and function keys are disabled. Diagnostic keys are also inoperative. If SVO resulted from a loss of gas supplies, <ALARM RESET> and <ALARM SILENCE> remain functional.

Emergency Modes of Ventilation

Emergency modes of ventilation are not intended for long-term ventilatory support. An emergency mode is invoked when the ventilator detects a significant change in the state of the patient or the ventilator.

Breath parameters may be selected by the operator for apnea and disconnect ventilation; factory-preset parameters apply for the BACK UP VENTILATOR mode.

Table 3-7 describes the causes, manifestations, and corrective actions associated with each ventilator-initiated emergency mode.

Table 3-7. Initiation and Cancellation of Emergency Modes

Ventilator-Initiated Emergency Mode	Cause	Enunciation	Action
Apnea ventilation	Apnea is detected and no LOW INSPIRATORY PRESSURE alarm exists (if in CMV or SIMV).	Apnea alarm active, [APNEA VENTILATION] appears in message window.	Check patient condition and the patient service system. Press <ALARM RESET>. (Auto-resets after the patient completes two consecutive breaths returning 50% of the set apnea tidal volume.)
Disconnect ventilation	Patient service circuit may be occluded, disconnected, or kinked.	Audible alarm sounds, ALARM display flashes, HIGH PRESSURE LIMIT indicator flashes, [AIRWAY PRESS DISCONN] appears in the message window.	Check patient service system and press <ALARM RESET>. Does not auto-reset.
Back up ventilation	Ventilator has failed a system error-initiated POST.	Audible alarm sounds, BACK UP VENTILATOR display illuminates.	Identify and correct problem. Do not use on a patient until repaired.
	Ventilator has detected the third system error in 24 hours.	Audible alarm sounds, BACK UP VENTILATOR display illuminates.	Identify and correct problem. Do not use on a patient until repaired.
	Supply voltage falls to less than 90% of rated value.	Audible alarm sounds, [LOW AC POWER] appears in message window, BACK UP VENTILATOR display illuminates.	Identify and correct problem. Do not use on a patient until supply voltage is restored to normal.
Safety Valve Open	Available gas supplies are nonfunctional.	Audible alarm sounds, SAFETY VALVE OPEN display illuminates, LOW PRESSURE O_2 INLET and LOW PRESSURE AIR INLET indicators flash, [SVO DUE TO LSP] appears in message window.	Provide alternate ventilatory support. Replace gas supplies and press <ALARM RESET>. If a compressor is installed, check the compressor circuit breaker.
	POST is running.	SAFETY VALVE OPEN display illuminates, no audible alarm.	None required. SAFETY VALVE OPEN is part of normal POST.
	Ongoing checks detect a system fault.	Audible alarm sounds, SAFETY VALVE OPEN display illuminates, VENTILATOR INOPERATIVE display illuminates. [ERR 99XX DO NOT USE] appears in message window, where 99XX is an error code.	Provide alternate ventilatory support. Record error code shown in message window. Do not use the ventilator until serviced.
	AC voltage is lost.	Audible alarm sounds, no displays visible.	Provide alternate ventilatory support. Check power cord, electrical outlet, and circuit breaker.

Table 3-8 describes the breath parameters and values employed during emergency ventilatory modes.

Table 3-8. Parameters/Thresholds and Values for Ventilator-Initiated Emergency Modes

APNEA/DISCONNECT VENTILATION	
	NOTE - The operator should enter values for tidal volume, respiratory rate, peak inspiratory flow, and O_2 for apnea ventilation consistent with normal parameters. These values are also used by the ventilator for disconnect ventilation.
Function	**Value/Availability in Apnea or Disconnect Ventilation**
Waveform	Square wave
PEEP/CPAP	Retains current setting; in Disconnect Ventilation, do not raise PEEP setting
Tidal Volume	Operator selects value from 0.10 to 2.5 liters (default: 0.5 liter)
Respiratory Rate	Operator selects value from 0.5 to 70 bpm (default: 12 bpm)
Peak Inspiratory Flow	Operator selects value from 10 to 120 Lpm (default: 45 Lpm)
Sensitivity	In Apnea Ventilation: retains current setting In Disconnect Ventilation: current setting remains in ventilator memory but is ignored (patient-initiated breathing unavailable)
O_2%	Operator selects value from 21 to 100% (default: 100% oxygen) If O_2 is unavailable, air is delivered.
Plateau	0.0 seconds (Plateau feature disabled)
High Pressure Limit	Retains current setting (In Disconnect Ventilation, patient pressure displays may be unreliable due to disconnection, occlusion, blocking, crimping, or the presence of condensate in the patient circuit.)
Low Inspiratory Pressure	0 (disabled)
Low PEEP/CPAP Pressure	0 (disabled)
Low Exhaled Tidal Volume	0 (disabled)
Low Exhaled Minute Volume	0 (disabled)
High Respiratory Rate	0 (disabled)
Low Pressure O_2 Inlet	*Effective, as in normal operation*
Low Pressure Air Inlet	Effective, as in normal operation
Automatic Sigh	Off (suspended)
100% O_2 Suction	Off (suspended)
Nebulizer	Off (suspended)
Alarm Silence	Effective, as in normal operation
Alarm Reset	Effective, as in normal operation
Lamp Test	Canceled, if selected
EST	Inoperative

Table 3-8. Parameters/Thresholds and Values for Ventilator-Initiated Emergency Modes (continued)

BACK UP VENTILATION

Function	Value/Availability in Back Up Ventilation
Waveform	Square
PEEP/CPAP Pressure	Retains current setting; do not raise PEEP setting
Tidal Volume	0.5 liter (Actual delivered volume is dependent on endotracheal tube size and flow rate.)
Respiratory Rate	12 bpm
Peak Inspiratory Flow	45 Lpm
Sensitivity	Ignored
O_2%	100% oxygen is administered if available; otherwise, air is used
Plateau	0.0 seconds (Plateau feature disabled)
High Pressure Limit	The BUV pressure switch limits pressure in the patient system to approximately 30 cmH_2O above PEEP
Low Inspiratory Pressure	0 (disabled)
Low PEEP/CPAP Pressure	0 (disabled)
Low Exhaled Tidal Volume	0 (disabled)
Low Exhaled Minute Volume	0 (disabled)
High Respiratory Rate	0 (disabled)
Low Pressure O_2 Inlet	Alarm nonfunctional; automatic gas supply switch-over circuits functional
Low Pressure Air Inlet	Alarm nonfunctional; automatic gas supply switch-over circuits functional
Automatic Sigh	Off (suspended)
100% O_2 Suction	Off (suspended)
Nebulizer	Off (suspended)
Alarm Silence	Inoperative
Alarm Reset	Inoperative
Lamp Test	Inoperative
EST	Inoperative

Postoperational Procedures

When the patient no longer requires ventilatory assistance, disconnect the patient from the ventilator. At this time, perform the following steps:

A. Turn off all equipment and disconnect the gas supplies (Figure 3-16).

1. Lower the ventilator PEEP knob to zero.
2. Turn off and disconnect all optional equipment (except for the 7202 Display).
3. Turn off the humidifier.
4. Turn off and unplug the ventilator.
5. Disconnect the gas supplies.
6. Drain water traps and inspect them.
7. Disconnect the 7202 Display (if necessary).
8. Disconnect the analog signal recorder or remote nurse's call (if used).

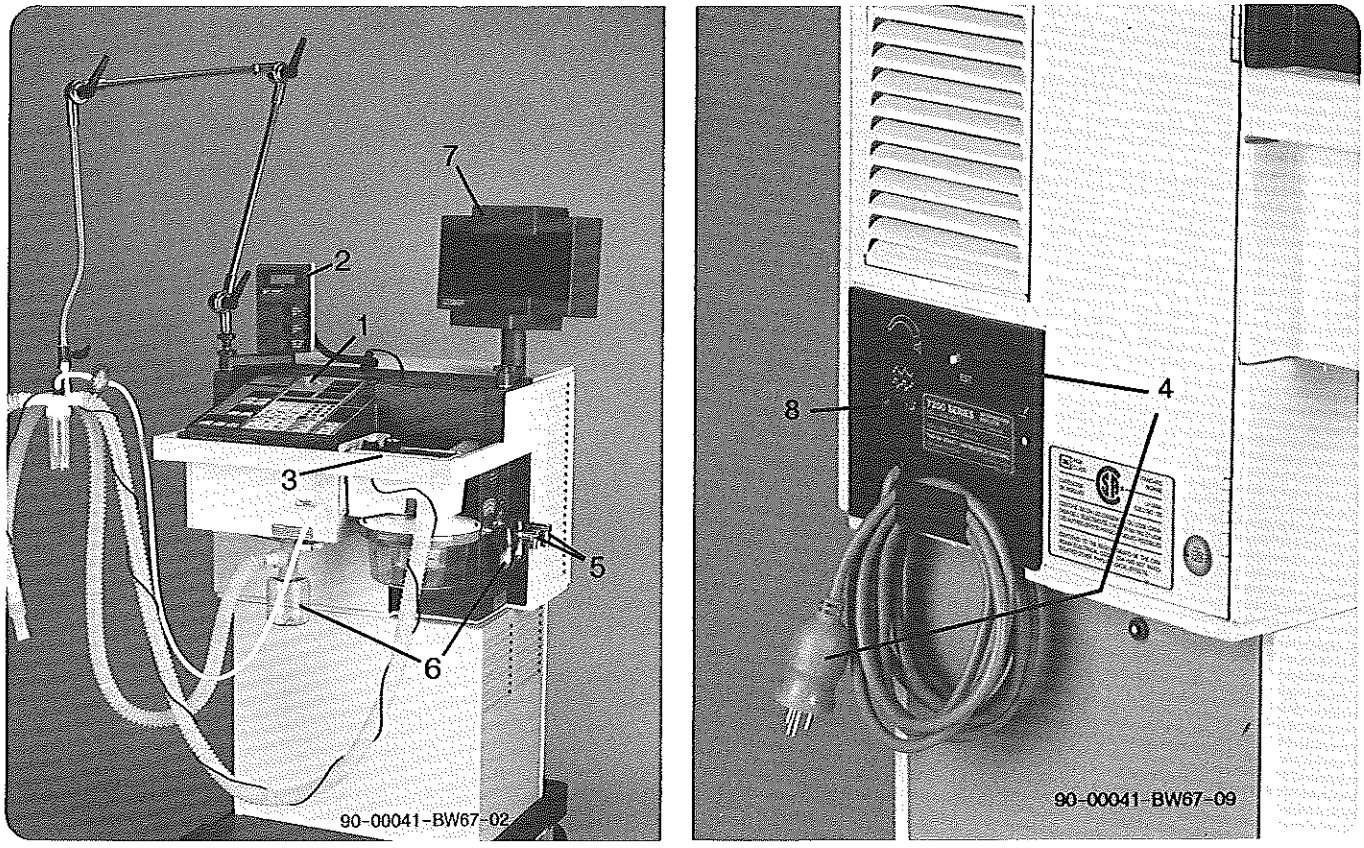


Figure 3-16. Turning Off Equipment

B. Remove monitoring sensors, if used (Figure 3-17).

1. Open main flow bacteria filter compartment door and guide cable from slot.
2. Remove sensor and tee adaptor.
3. Disconnect temperature sensor.

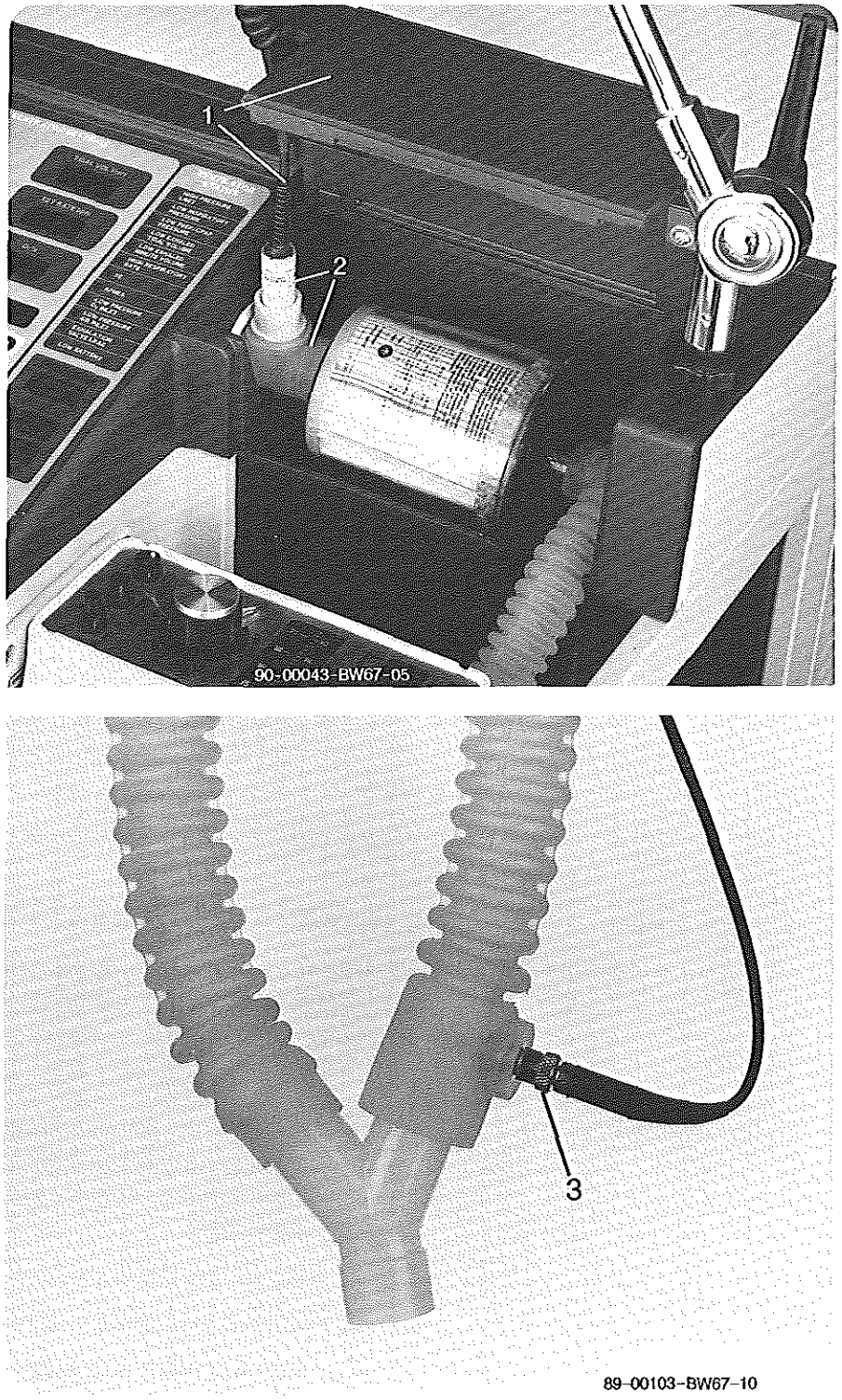


Figure 3-17. Removing Monitoring Sensors

C. Remove the simplified circuit by detaching its limbs from connections at the humidifier outlet, the collector vial, and the patient wye. Remove the tube hanger from the flex arm (Figure 3-18).

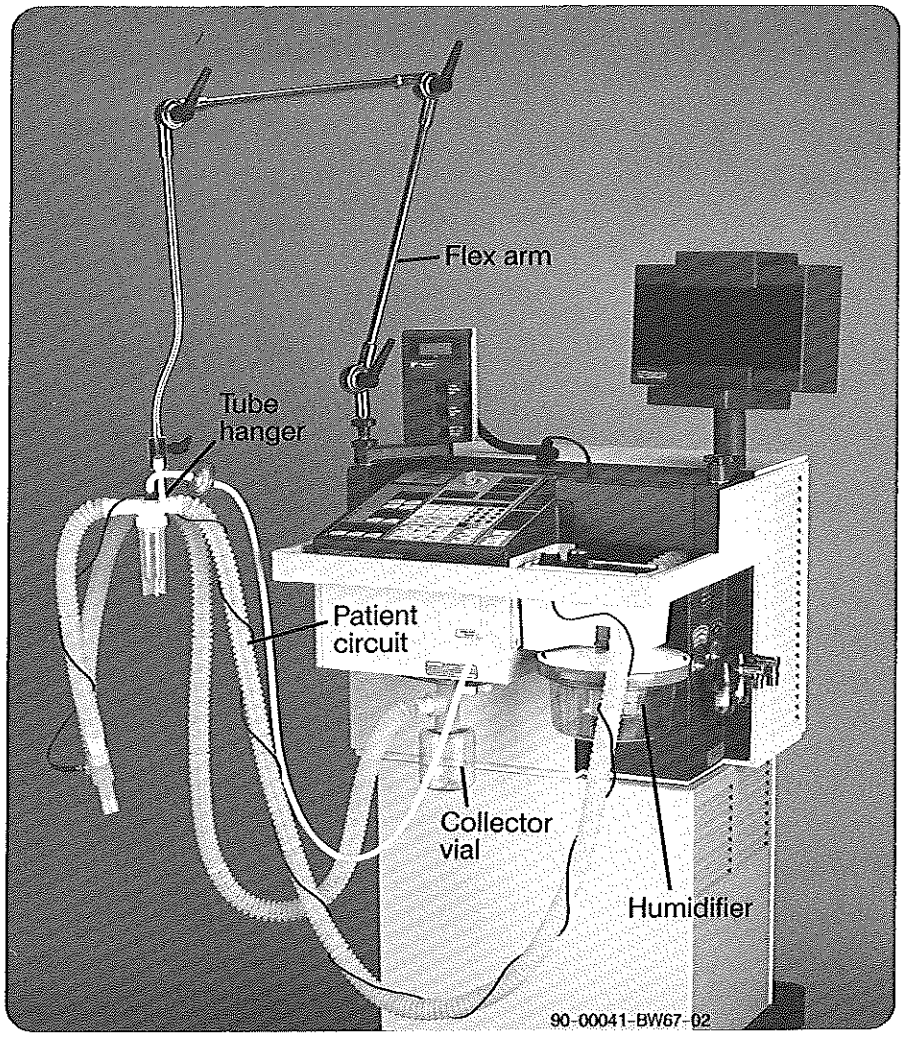


Figure 3-18. Removing the Patient Service Circuit

D. Remove the components of the humidifier circuit, as illustrated in Figure 3-19. (The Cascade II Humidifier is shown; for other humidifiers, refer to the appropriate operator's manual for removal instructions.)

WARNING *- To avoid risk of burns, allow the Cascade II Humidifier to cool at least 15 minutes before removing it. If another humidifier is used, consult the operator's manual for the required cool-down time.*

1. Disconnect the humidifier inlet tube.
2. Remove jar, cover, and heater.
3. Open the main flow bacteria filter compartment door.
4. Disconnect the tubing from the filter.
5. Remove the main flow bacteria filter.

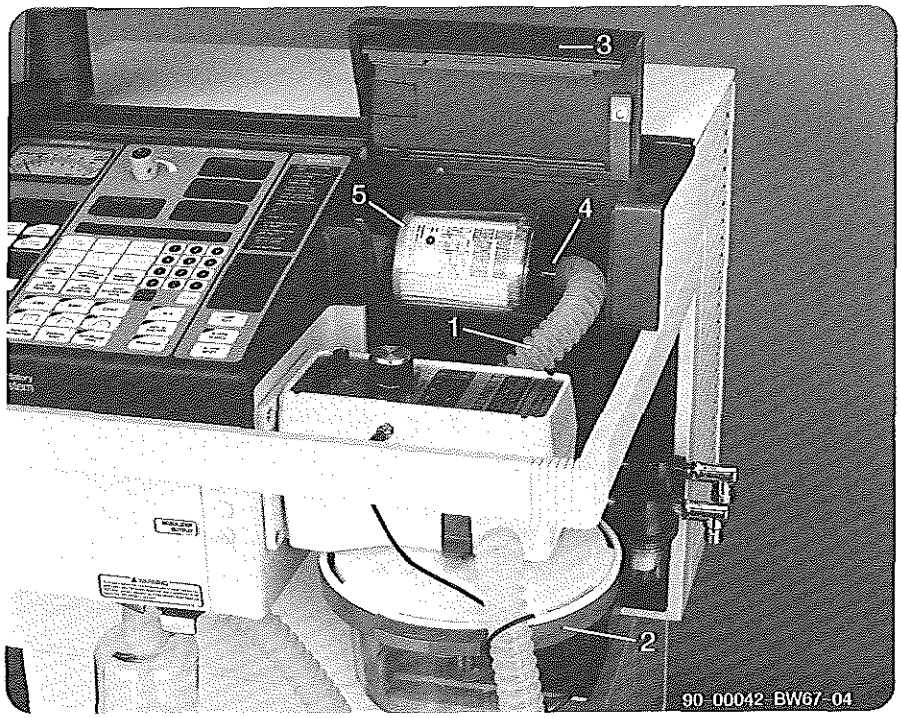
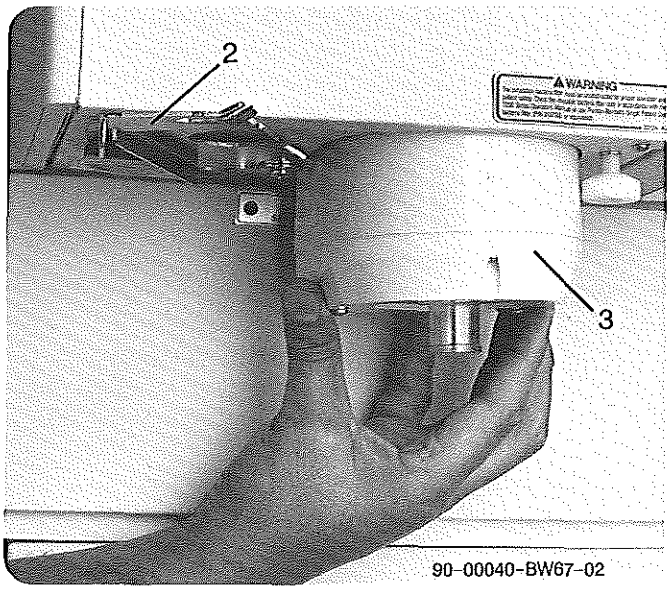


Figure 3-19. Removing the Humidifier

E. For bottom-loading exhalation compartments, remove the exhalation bacteria filter.

1. Remove collector vial and tee.
2. Swing out filter clamp (Figure 3-20).
3. Pull out filter and heater assembly from compartment.
4. Remove filter from heater.

CAUTION - Forcing the heater into the compartment could damage the assembly. When installing the heater, allow the electrical connection to mate properly.



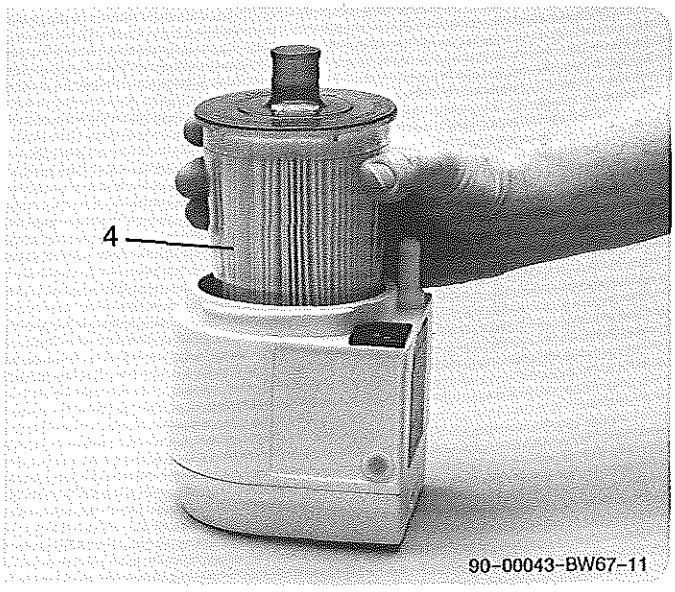


Figure 3-20. Removing the Exhalation Bacteria Filter

Summary for Selecting Ventilator Settings

Table 3-9 summarizes how to select ventilator functions.

Table 3-9. Selecting Ventilator Functions

Function	How Specified	Indicators
Mode (CMV, SIMV, or CPAP)	1) Press mode key. 2) Press <ENTER>.	1) Mode name and [ENTER] prompt appear in message window. 2) Indicator lights on mode key and two beep tones sound.
Waveform (Square, Descending Ramp, or Sine)	1) Press waveform key. 2) Press <ENTER>.	1) Waveform name and [ENTER] prompt appear in message window. 2) Indicator lights on waveform key and two beep tones sound.
Breath Parameter (Tidal Volume, Respiratory Rate, Peak Inspiratory Flow, Sensitivity, O_2%, or Plateau)	1) Press breath parameter key. 2) Key in numeric value for parameter. 3) Press <ENTER>.	1) Parameter name and current setting appear in message window. 2) New value appears in message window. 3) Two beep tones sound and new setting is accepted. (Four beep tones indicate an entry error; see Error Messages in this chapter.)
Alarm Threshold (High Pressure Limit, Low Inspiration Pressure, Low PEEP/CPAP Pressure, Low Exhaled Tidal Volume, Low Exhaled Minute Volume, or High Respiratory Rate)	1) Press alarm threshold key. 2) Key in numeric value. 3) Press <ENTER>.	1) Threshold name and current setting appear in the message window. 2) New value appears in message window. 3) Two beep tones sound and new setting is accepted. (Four beep tones indicate an entry error; see Error Messages in this chapter.)
100% O_2 Suction (turns on or off)	1) Press <100% O_2 SUCTION> key. 2) Press <ENTER>.	1) Function name and [ENTER] prompt appear in message window. 2) Two beep tones sound; indicator lights while function is active (up to two minutes) and goes out when inactive.
Manual Inspiration, Manual Sigh (with sigh parameters specified via <AUTOMATIC SIGH> key)	Press desired key.	Breath is delivered (except if mandatory inspiration in progress); two beep tones sound; for sighs, the SIGH indicator lights in the PATIENT DATA section.

Table 3-9. Selecting Ventilator Functions (continued)

Function	How Specified	Indicators
Automatic Sigh *(turns on or off)*	1) Press <AUTOMATIC SIGH> key. 2) Press <ENTER>. 3) Key in values for each parameter and press <ENTER>. 4) Press <ENTER>. 5) Choose manual or automatic sigh: a) Stop here to specify manual sigh *parameters only (do not press* <ENTER>), *or* b) Press <ENTER> to activate *automatic sigh; press <CLEAR> to* keep automatic sigh off.	1) Function name and the [ENTER] prompt appear in the message window. 2) The parameter prompt appears. 3) As each value is entered, the next prompt appears. When all parameters have been specified, the update prompt appears. 4) The [AUTOMATIC SIGH ON ENTER] *prompt appears.* 5) Indicator lights on Automatic Sigh key and goes out when the feature is inactive; two beep tones sound.
Nebulizer (turns on or off)	1) Press the <NEBULIZER> key. 2) Press <ENTER>.	1) Function name and [ENTER] prompt appear in the message window. 2) Indicator lights on Nebulizer key and goes out when the feature is inactive; two beep tones sound.
<++> Key Functions (In general)	1) Press the <++> key. 2) *Select function number:* a) Press <ENTER> if displayed function is the one desired, *or* b) Press key(s) for function number and press <ENTER>, *or* c) Press <++> key or <*> key to scroll forward or backward to function number, and press <ENTER>. 3) Press <ENTER>. 4) Key in value for each function parameter and press <ENTER>. (See Selecting <++> Key Functions, Table 3-4, or appropriate option appendix for details.) 5) Press <ENTER>.	1) Function select prompt appears. 2) Function name appears. 3) Parameter prompt appears. 4) As each value is entered, the next parameter prompt appears. When all parameters have been specified, the update prompt appears. 5) Parameters-on message appears; indicator lights on <++> key while function is active.

Care and Maintenance 4

Introduction

Procedures such as cleaning, sterilizing and periodic maintenance must be performed to ensure consistent ventilator operation. This chapter recommends methods and time frames for performing these care and maintenance procedures for the 7200ae Ventilator. These should be adapted to your institution's policies and protocols.

Cleaning and Sterilizing

This section describes general procedures for cleaning and sterilizing some parts of the 7200ae Ventilator, daily and between patients. Some ventilator parts must be disassembled before cleaning and sterilizing. Table 4-1 gives specific recommendations for cleaning and sterilizing parts and ventilator surfaces.

NOTE - Puritan-Bennett recognizes that cleaning, sterilization, sanitation, and disinfection practices vary widely among health care institutions. It is not possible for Puritan-Bennett to specify or require specific practices that will meet all needs, or to be responsible for the effectiveness of cleaning, sterilization, and other practices carried out in the patient care setting.

Puritan-Bennett does recommend that users of its products, which require cleaning and sterilization/disinfection, consider the *National Standards and Recommended Practices for Sterilization* published by the Association for the Advancement of Medical Instrumentation (AAMI), as well as the following Center for Disease Control (CDC) publications: *Guidelines for Maintenance of In-Use Respiratory Therapy Equipment* and *Guidelines for Prevention of Nosocomial Pneumonia.*

Table 4-1. Cleaning and Sterilizing of Ventilator Parts and Surfaces

Part	Recommended Action	Cautions
Ventilator exterior, front panel, and console cover	Wipe clean with a damp cloth and mild detergent.	Do not use liquid bactericide. Do not allow moisture to sit between keyboard panel and console cover.
All other outside surfaces, including flex arm	Wipe clean with alcohol or bactericide.	Do not allow liquid to penetrate the ventilator or keyboard display panel. Do not attempt to sterilize the ventilator by exposing to ETO gas.
Gas supply water traps	Wash in mild solution of soap and water.	Do not steam-autoclave, chemically disinfect, or expose to ETO gas.
Accessory equipment surfaces	Wipe clean with a damp cloth and mild detergent.	Consult appropriate operator's manual for details.
Patient tubing	Disassemble and clean. (See Figure 4-1 to disassemble.) Then steam-autoclave, chemically disinfect, or expose to ETO gas.	If submerged in liquid during cleaning and sterilizing, blow moisture from inside tubing with pressurized air before using. Inspect for nicks and cuts.
In-line water traps	Disassemble and clean. Then steam-autoclave, chemically disinfect, or expose to ETO gas.	Check for cracks.
Nebulizer	Disassemble and clean. Then steam-autoclave, chemically disinfect, or expose to ETO gas.	Ensure that nebulizer jet passages are cleaned with the jet cleaning rod provided with the nebulizer.
Couplings and connectors	Steam-autoclave or chemically disinfect.	If submerged in liquid during cleaning and sterilizing, blow moisture from inside with pressurized air before using. Inspect for nicks and cuts.
Collector vial	Clean and steam-autoclave, chemically disinfect, or expose to ETO gas.	Check for cracks.
Bacteria filters	Steam-autoclave reusable filters. Discard disposable or single-patient use filters.	Do not chemically disinfect or expose to ETO gas. Check resistance of filter before reusing. (See Figure 4-2 and Figure 4-3.)
Exhalation flow sensor and internal exhalation valve	Do NOT clean.	Do not attempt to remove the flow sensor and valve. Do not flush them with liquids or pressurized air. To clean the exhalation flow circuit, remove and clean the exhalation bacteria filter, collector vial, and tee. No further cleaning is required.

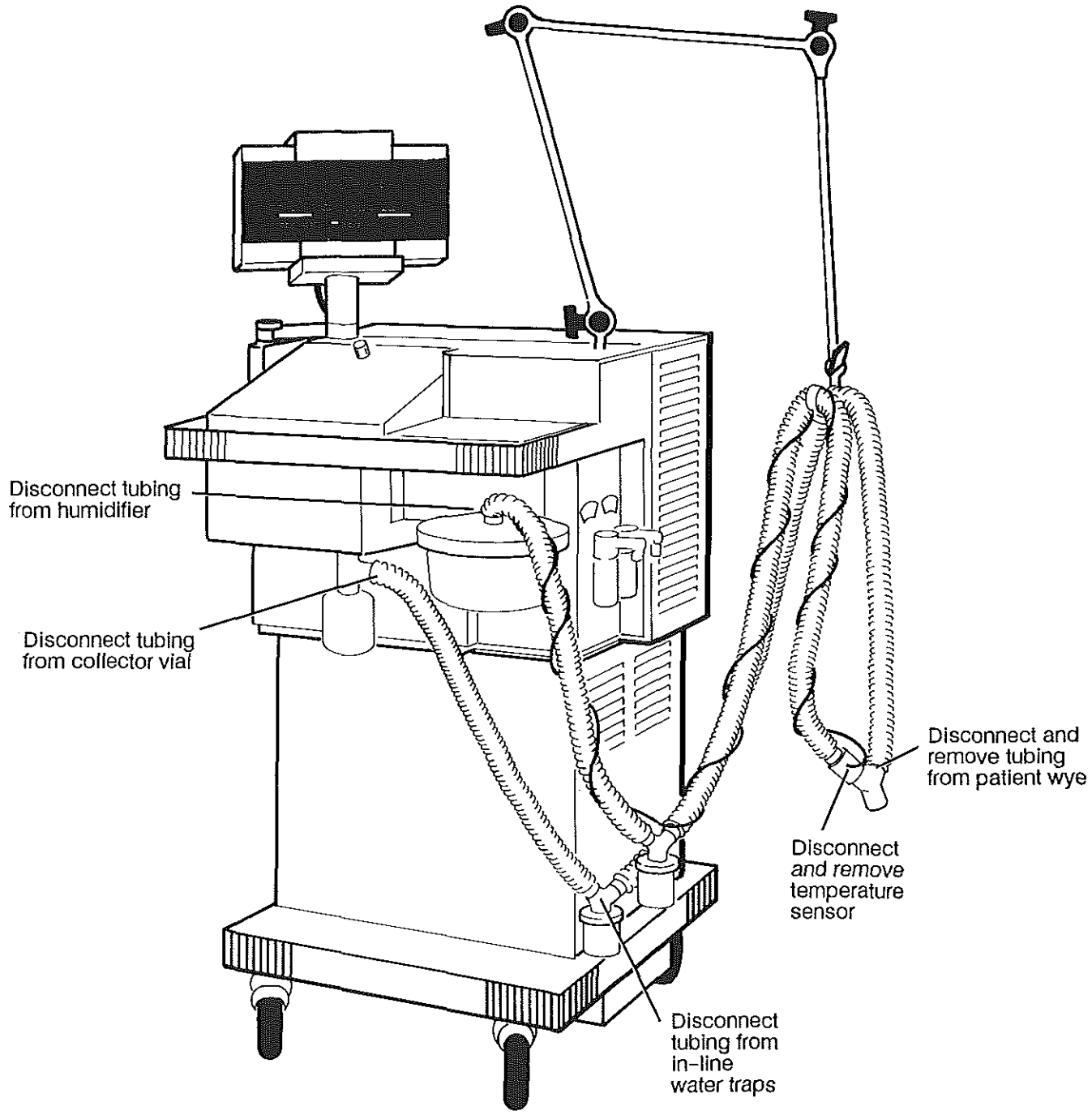


Figure 4-1. Disassembly of the Patient Service Circuit

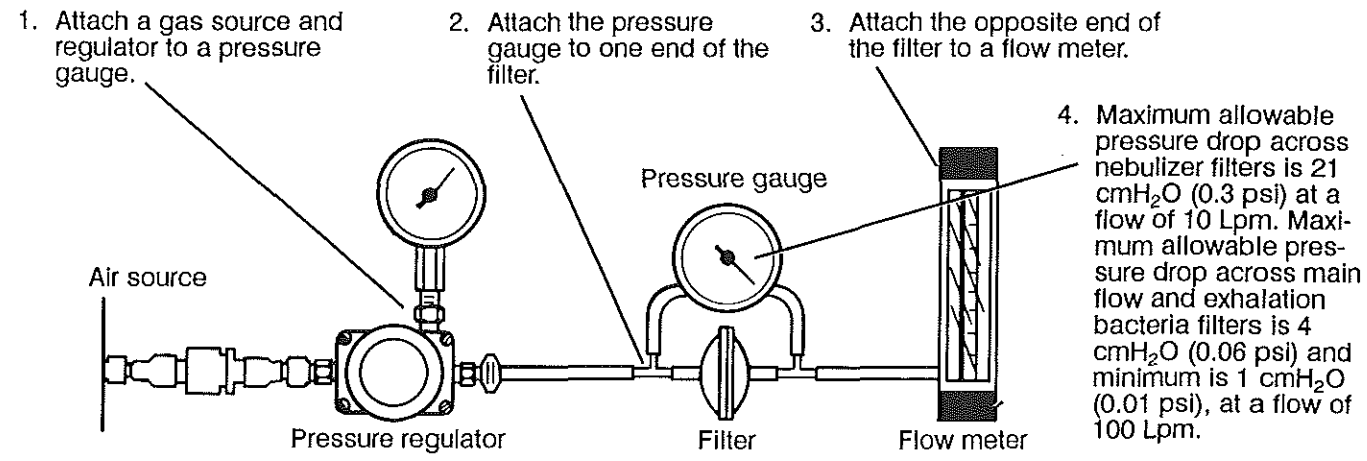
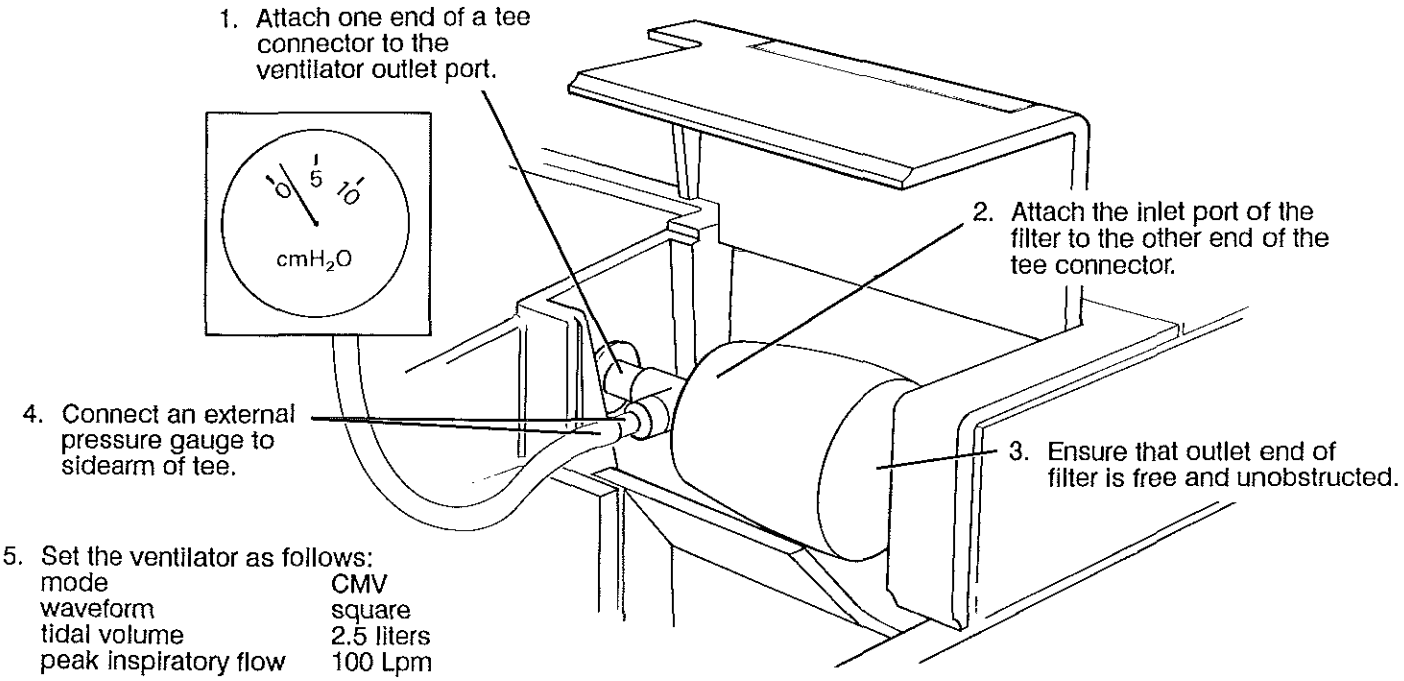


Figure 4-2. Measuring Resistance of the Bacteria Filters with a Metered Air Source



5. Set the ventilator as follows:

mode	CMV
waveform	square
tidal volume	2.5 liters
peak inspiratory flow	100 Lpm

6. Press <MANUAL INSPIRATION> and read pressure on the calibrated external pressure gauge.

7. The filter must be replaced if the pressure drop is:
   - greater than 4 cmH_2O (0.06 psi), indicating occluded filter material, or
   - less than 1 cmH_2O (0.01 psi), indicating the filter material may be ruptured.

Figure 4-3. Measuring Resistance of the Bacteria Filters with an External Gauge

Cleaning

When cleaning parts, avoid the use of hard brushes or other instruments likely to cause surface damage.

1. Wash parts in warm water and detergent.

CAUTION – Follow the detergent manufacturer's instructions. Exposure to detergent solution stronger than necessary can shorten the useful life of the product. Rinse parts thoroughly to remove all detergent residue. Wipe parts dry. Detergent residue can cause blemishes or fine cracks, especially on parts exposed to elevated temperatures during sterilization.

2. Rinse parts thoroughly in clean, warm water (tap water is acceptable).
3. Wipe parts dry.
4. *Puritan-Bennett recommends that all parts be inspected each time they are cleaned.*

Sterilization/Disinfection

Some parts of the ventilator can be steam autoclaved, exposed to ETO gas, or immersed in appropriate chemical disinfectant solutions.

NOTE – Because conditions and practices in health care institutions vary, this manual can only describe general guidelines for these three methods. It is the user's responsibility to ensure the validity and effectiveness of the methods used.

The cleaning, sterilizing, and reuse of single-patient use and disposable products is not recommended.

When sterilizing tubing, coil the tubing in a large loop, avoiding kinks and crossover of tubing on tubing. The lumen should be free of any visible droplets prior to wrapping.

WARNING – *Because some components that come into contact with inspired gases may absorb certain sterilizing agents, they may be sterilized by only one or two of the techniques described. For patient's safety, heed the cautions listed in Table 4-1. With other components, exposure to sterilizing agents may reduce their useful life.*

The sterilization/disinfection method determines in what order these steps are performed:

Steam autoclaving or ETO exposure

1. Disassemble.
2. Clean.
3. Inspect.
4. Reassemble.
5. Sterilize.

Chemical disinfection

1. Disassemble.
2. Clean.
3. Inspect.
4. Disinfect.
5. Reassemble.

Steam Autoclaving

CAUTION – Autoclavable parts will withstand repeated steam autoclaving at temperatures not to exceed 135 °C (275 °F).

1. Ensure that the part has been disassembled, cleaned, and partially reassembled, as applicable.
2. Separately wrap the part in muslin or equivalent paper wrapper.

3. Steam-autoclave according to the autoclave manufacturer's instructions. In many institutions it may be routine to place a biological indicator in the autoclave load as a subsequent test for sterility.
4. Aseptically store the part until use.

Exposure to ETO Gas

1. Ensure that the part has been disassembled, cleaned, and partially reassembled, as applicable.
2. Separately wrap the part in packaging that is suitable for ETO sterilization.
3. Place the part in an ETO sterilizer and expose to a gas sterilizing cycle recommended by the sterilizer manufacturer, or a cycle validated by your health care institution.
4. Place the part in an ETO aerator and degas for a time and at a temperature recommended by the aerator manufacturer or found to be satisfactory by your health care institution. Use proper aeration technique to ensure elimination of residual ETO.
5. Aseptically store the part until use.

Chemical Disinfection

For chemically disinfected parts, reassemble *after* disinfecting.

CAUTION – Formaldehyde and phenol-based disinfectants are not recommended because these agents can cause cracking and crazing of plastic parts. Exposure of components to disinfectant concentrations stronger than required or for excessive time may shorten product life. Parts should be thoroughly rinsed and dried to prevent spotting and blemishes when exposed to elevated temperatures. Refer to Puritan-Bennett Product Catalogs for materials of some sterilized parts.

1. Separately immerse each part in the chemical disinfectant. Follow the disinfectant manufacturer's directions for the solution concentration, immersion times, and other conditions for disinfection. The use of a laminar air-flow hood during the chemical disinfection process is recommended.
2. Thoroughly rinse and dry each part.
3. Aseptically reassemble (as required) and store the part until use.

Periodic Maintenance

This section includes detailed operator maintenance. Table 4-2 summarizes these procedures. Refer to the elapsed time meter located on the back of the ventilator for total hours of operation (Figure 4-4).

Table 4-2. Schedule for Periodic Maintenance

Frequency Required	Component	Maintenance
Daily	Nebulizer bacteria filter, main flow bacteria filter, exhalation bacteria filter	Check filters daily for occlusions and tears. Ensure that the ventilator functions normally with them in place. Monitor performance of disposable filters and replace as needed. Measure resistance of reusable filters after sterilization.
	Exhaled gas collector vial, oxygen supply water trap and filter, air supply water trap and filter	Check and empty, as required, every shift.
250 Hours	Compressor compartment cooling fan filter*, electronics compartment cooling fan filter*	Clean. (A screwdriver may be required to remove filters.)
2,500 Hours	Various components	Use 2,500-hour preventive maintenance kits.
10,000 Hours	Various components	Use 10,000-hour preventive maintenance kits.
Annually	Nebulizer bacteria filter, main flow bacteria filter, and exhalation bacteria filter (reusable filters only)	Replace and destroy reusable filters.

***NOTE** – Clean the fan filters more often than every 250 hours if necessary. (Some environments cause a quicker collection of lint and dust.)

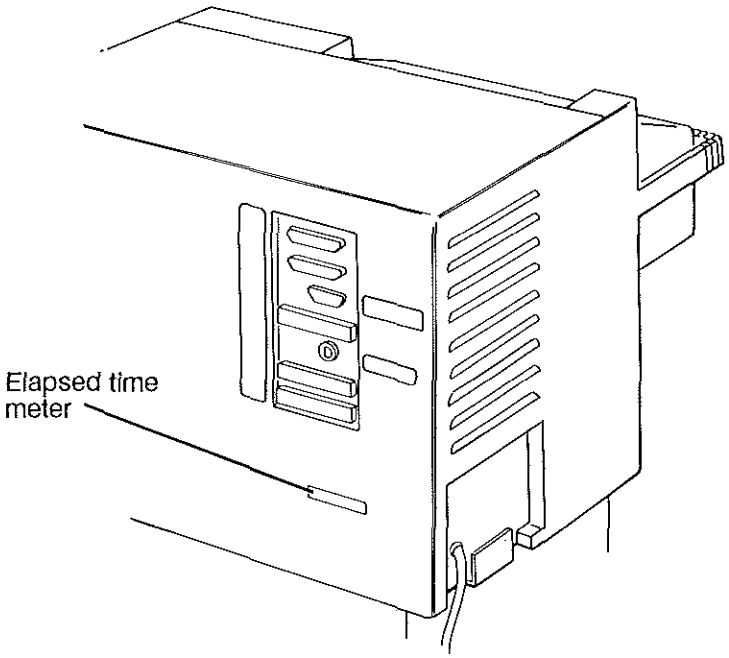


Figure 4-4. Location of Elapsed Time Meter

Daily: Main Flow and Exhalation Bacteria Filters

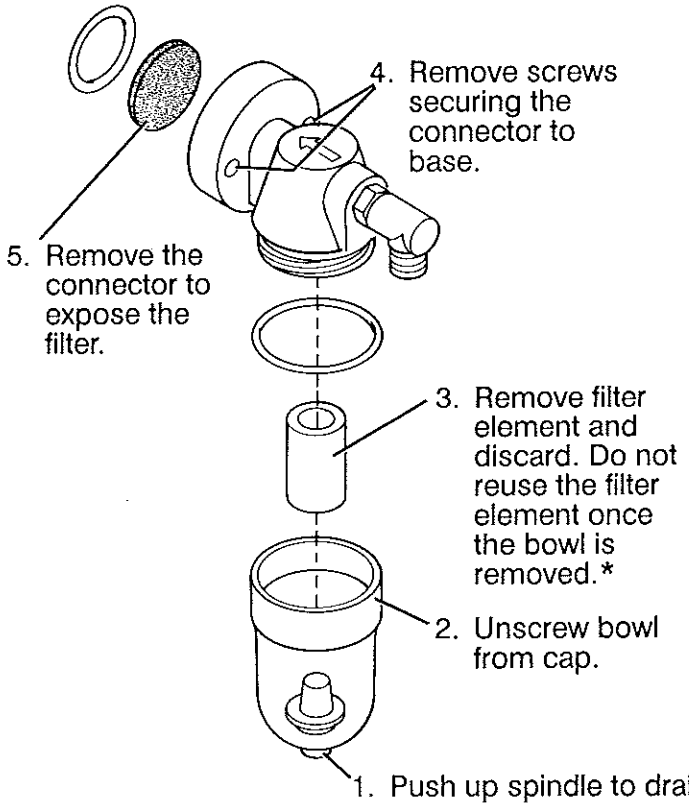
The maximum allowable pressure drop across a new main flow or exhalation bacteria filter is 4 cmH_2O (0.06 psi) at a flow of 100 Lpm. (Refer to Figure 4-2 or Figure 4-3 for how to measure resistance.) Replace the filter if:

- the measured pressure drop exceeds 4 cmH_2O, which may indicate an occluded filter medium, or
- the measured pressure drop is less than 1 cmH_2O, which may indicate a ruptured filter medium.

Daily: Gas Supply Water Traps and Filters (Air and Oxygen)

Visually inspect each trap and filter for buildup of condensate or particulate contaminants during each shift (or as often as is appropriate, based on previous experience). To purge condensate, press or loosen the drain valve at the bottom of the trap. See Figure 4-5 or Figure 4-6 for reference in disassembling the water traps and filters.

When the trap requires cleaning (less often than daily), wash it in a mild solution of soap and water, rinse well, and dry. For water traps with the spring-type drain, discard and replace the filter element when the bowl is removed.



***CAUTION** – Replace the filter element each time the bowl is removed. The filter element is pressed into place and when removed, it remains compressed. If the element is reused, filtering efficiency is reduced.

Figure 4-5. Disassembling the Gas Supply Water Trap and Filter Assembly (spring-type drain)

Daily: Nebulizer Bacteria Filter

The maximum allowable pressure drop across a new nebulizer bacteria filter is 21 cmH_2O (0.3 psi) at a flow of 10 Lpm. If the measured pressure drop exceeds this maximum, the filter must be replaced. The filter should be inspected and replaced if the filter medium is punctured. (See Figure 4-2 for how to measure resistance.)

NOTE – Since relatively high pressure powers the nebulizer, particle buildup is not a problem unless it is severe enough to reduce nebulizer performance.

Daily: Exhaled Gas Collector Vial

Inspect this water trap frequently when the ventilator is operating to ensure than an excessive amount of condensate has not accumulated. Empty the vial by removing from the circuit.

The vial should be cleaned, as necessary, in a solution of soap and water, to prevent buildup of residue. Thoroughly rinse, dry, and sterilize before returning to use.

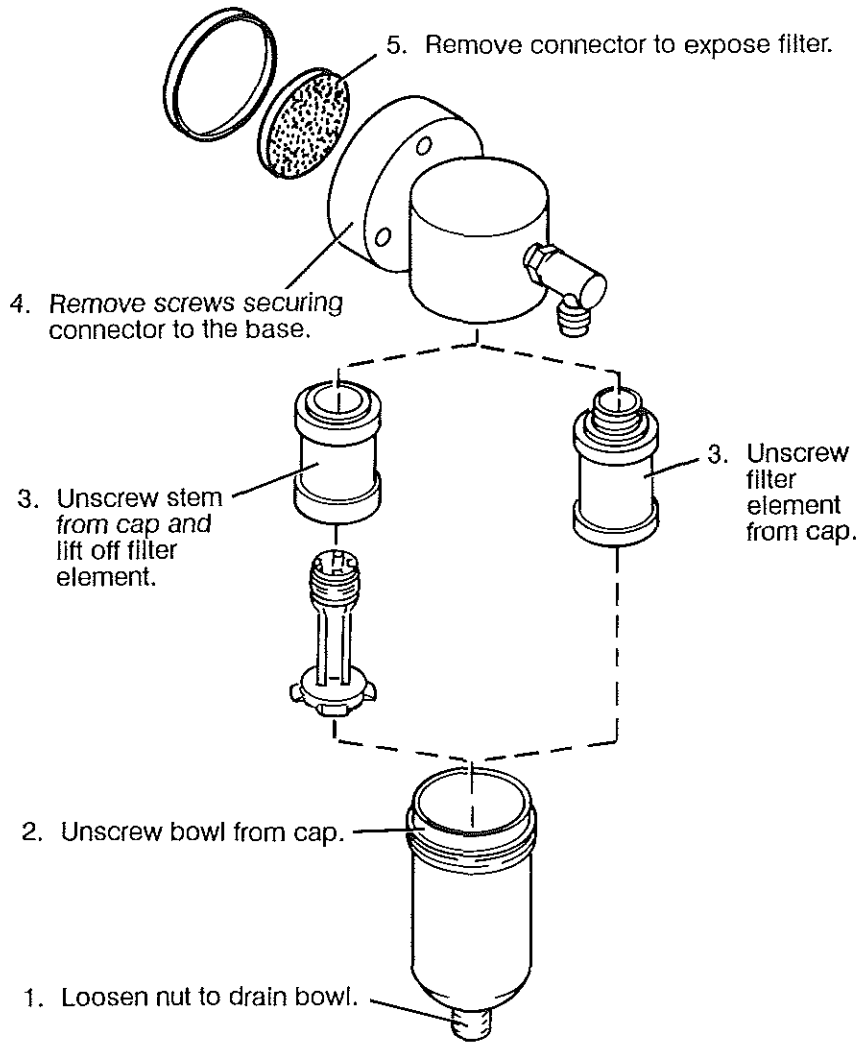


Figure 4-6. Disassembling the Gas Supply Water Trap and Filter Assembly (screw-type drain)

Every 250 Hours

Clean the electronics compartment cooling fan filter and compressor cooling fan filter (if the ventilator has a compressor) every 250 hours. See Figure 4-7 and Figure 4-8 to remove the filters.

Wash each filter in a mild solution of soap and water, rinse well, and dry, to ensure an unrestricted flow of air through the compartments.

NOTE – Clean the fan filters more often than every 250 hours if necessary. (Some environments cause a quicker collection of lint and dust.) It may be necessary to clean the compressor filter more often due to its tendency to collect lint.

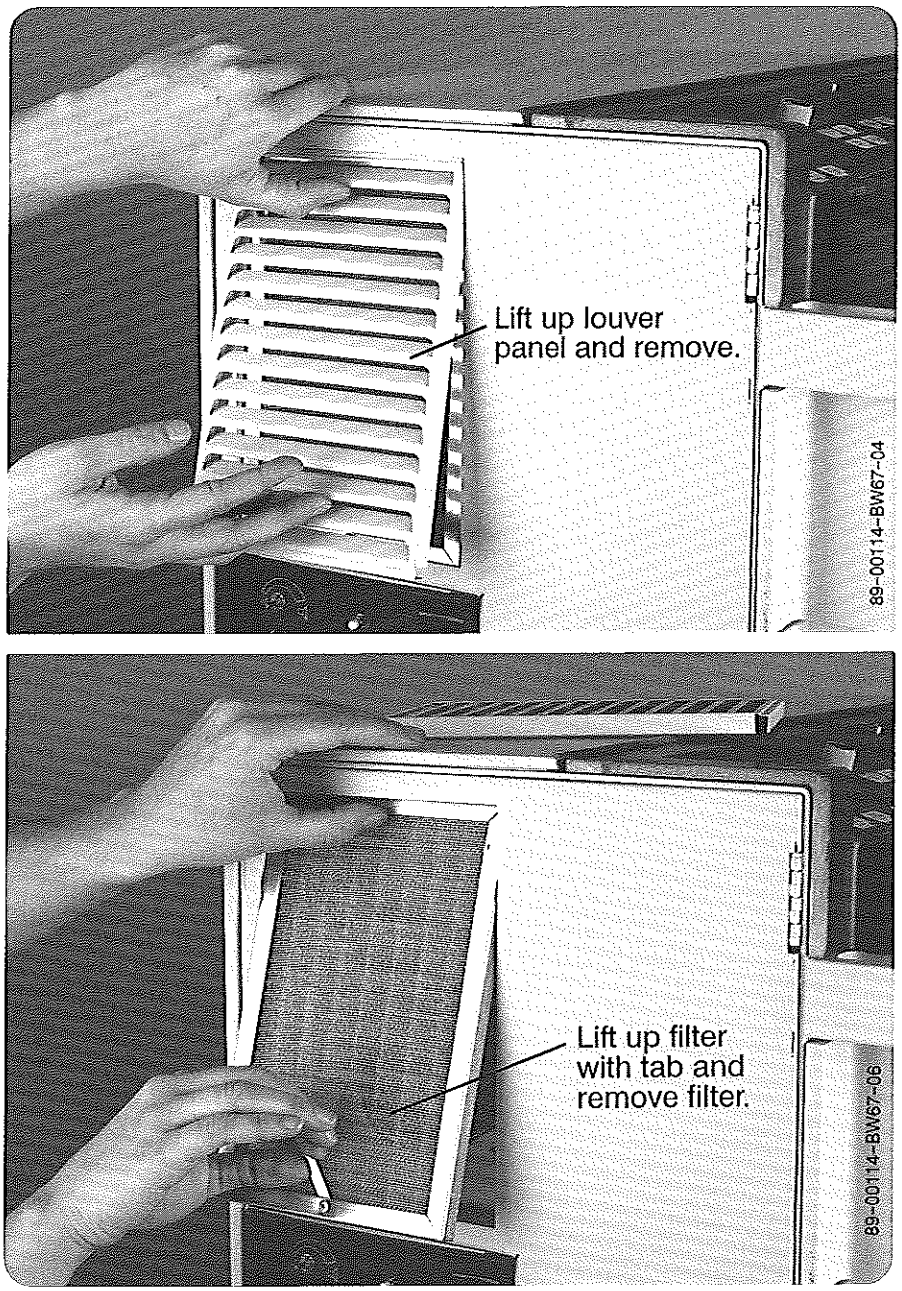


Figure 4-7. Removing the Electronics Compartment Cooling Fan Filter

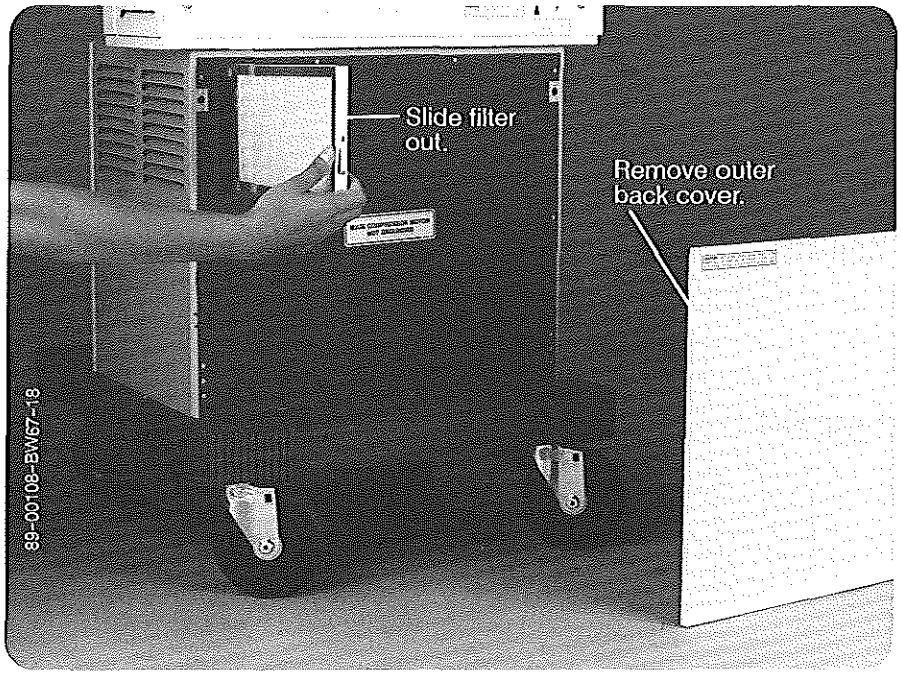


Figure 4-8. Removing the Compressor Compartment Cooling Fan Filter

Every 2,500 and 10,000 Hours

Puritan-Bennett recommends that a technician perform preventive maintenance at every 2,500 and 10,000 hours of service. Table 4-3 lists the kits available for these scheduled maintenance procedures.

Table 4-3. Preventive Maintenance Kits

Preventive Maintenance for:	Hours of Service	Kit Part Number
Ventilator, all voltages and frequencies	2,500 (Level I)	4-020291-00
Compressor, all voltages and frequencies		4-020292-00
Ventilator, 115 V, 60 Hz	10,000 (Level II)	4-020790-00
Ventilator, 220/240 V, 50/60 Hz		4-020804-00
Ventilator, 100 V, 50/60 Hz		4-020803-00
Ventilator, 115 V, 60 Hz		4-020791-00
Ventilator, 220/240 V, 50 Hz		4-020801-00
Ventilator, 220 V, 60 Hz		4-020802-00
Ventilator, 100 V, 50 Hz		4-020798-00
Ventilator, 100 V, 60 Hz		4-020799-00

Annually

Replace these reusable filters after one year of service, regardless of their apparent condition: nebulizer bacteria filter, main flow bacteria filter, and exhalation bacteria filter. (For disposable and single-patient use filters, follow manufacturer's recommendations.)

Self-Diagnostics

The ventilator has several tests by which it can self-diagnose certain problems. For example the lamp test checks keyboard operation and the battery check tests battery power. Other major self-diagnostics are the ventilator's self-tests; Chapter 5 describes them in detail.

Lamp Test

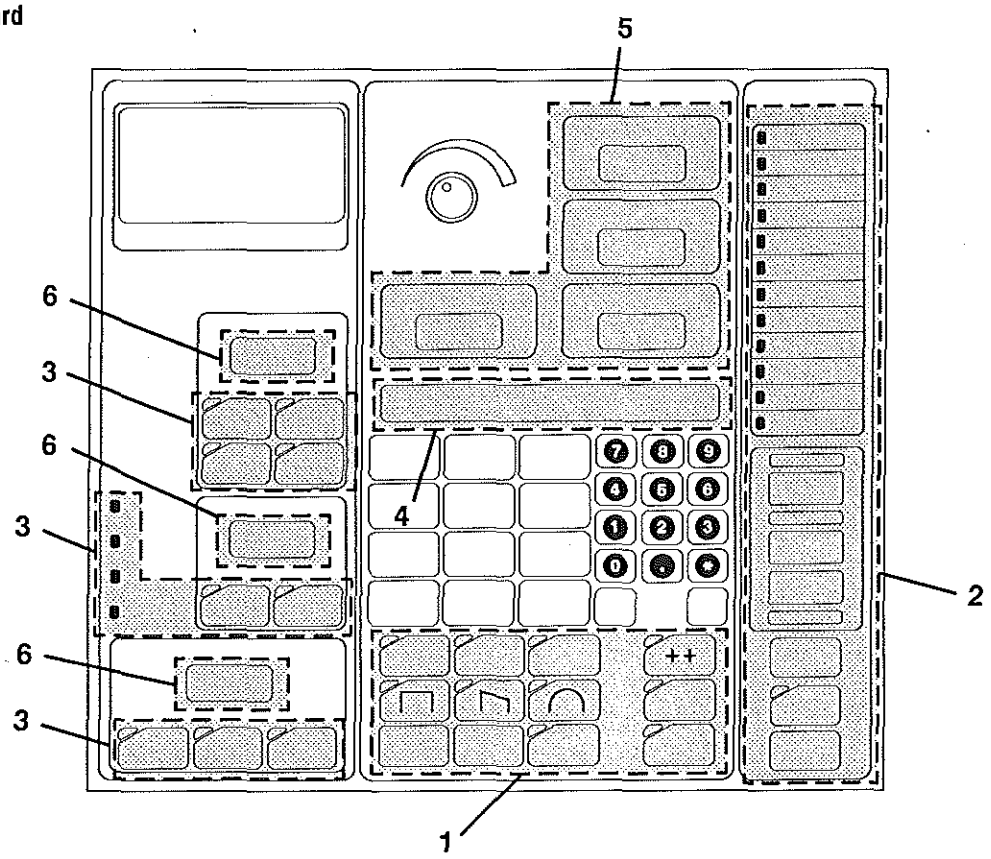
Initiate the lamp test by pressing the <LAMP TEST> key. Lamp test checks six sections of the ventilator keyboard display panel as shown in Figure 4-9. The sections are numbered 1 through 6 to indicate the order in which they are tested. As one section is being tested, it illuminates and the others remain blank. After all sections are tested, the sequence repeats. To cancel lamp test, press any key at any time during the test. If the ventilator detects an emergency condition, it cancels the test.

When lamp test first starts, the message display window shows the current software level of the ventilator. Then the tests of the sections begin; each section test takes a few seconds. During the tests of sections 1 through 3, the indicators flash. While sections 4 through 6 are tested, the displays illuminate but do not flash. The audible alarm sounds while sections 2, 3, 4, and 6 are being tested, and the remote nurse's call is activated while section 1 is being tested.

The analog meter and the signals for the analog signal recorder are checked while sections 2 through 6 are being tested. The meter's needle and the recorder's signal are set to 25% of full-scale deflection while section 2 is being tested, to 50% while section 3 is being tested, to 75% while sections 4 and 5 are being tested, and to 100% while section 6 is being tested.

Have any indicator light or display replaced that does not illuminate when tested, before the ventilator is used. Replacing indicator lights or displays usually requires removal of the keyboard display panel and should only be performed by a qualified service technician. (For Basic keyboards, instructions for replacing the alarm summary bulbs are shown in Figure 4-10.)

Enhanced Keyboard



Basic Keyboard

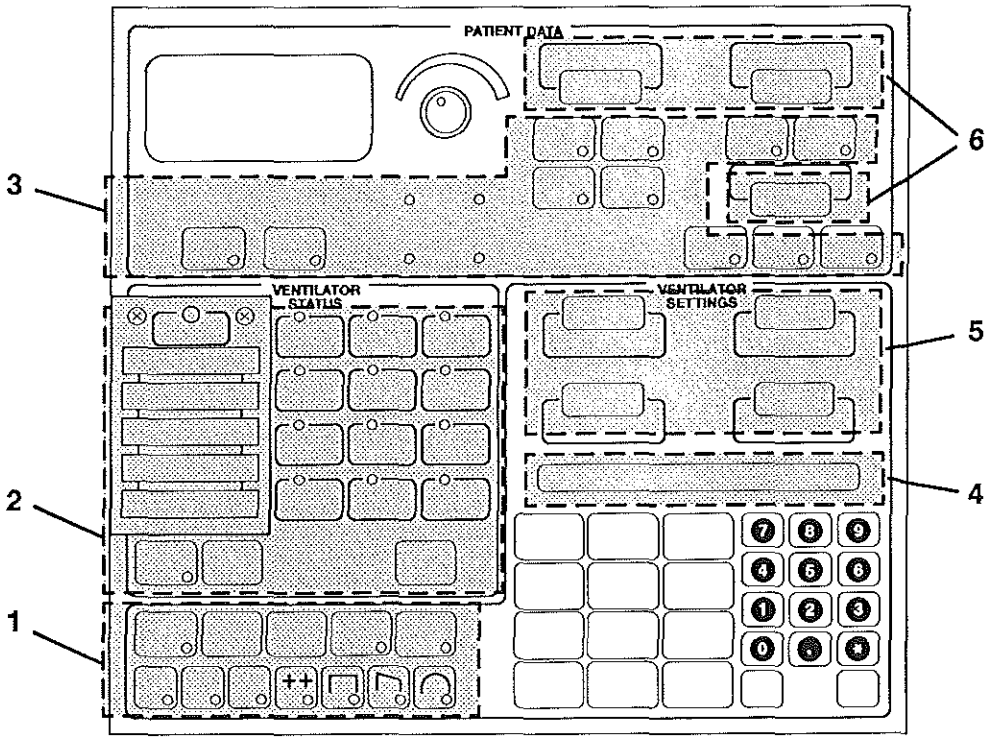


Figure 4-9. Lamp Test Keyboard Section Sequence

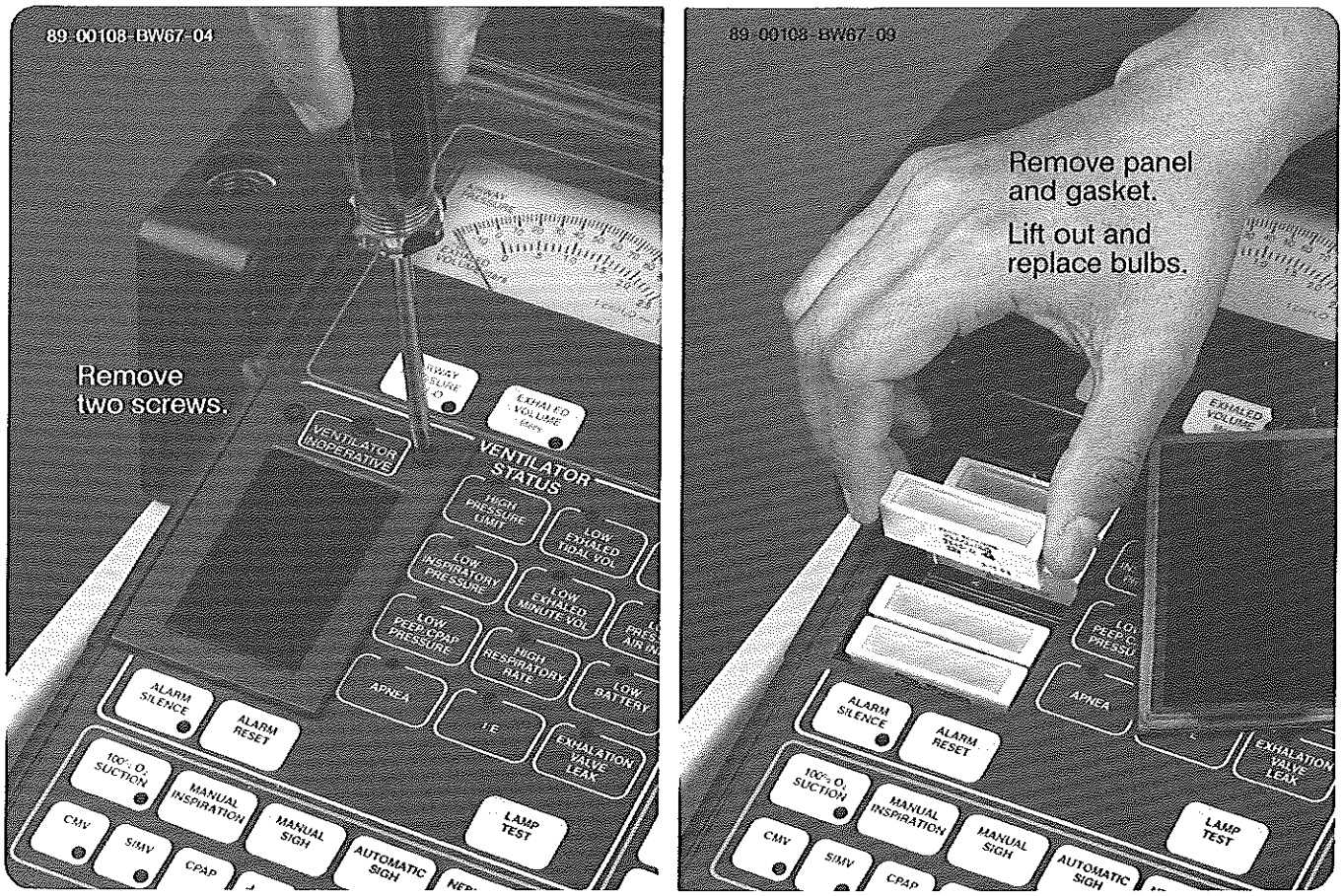


Figure 4-10. Replacing Alarm Summary Display Bulbs in Basic Keyboard

Battery Check

Sufficient power in the internal batteries is important for proper ventilator operation. Low batteries should be replaced as soon as possible to ensure accurate equipment function.

> ***WARNING*** – *Do not replace the batteries while the patient is connected to the ventilator.*

The ventilator tests battery power each hour. You may also check the batteries by pressing <ALARM RESET>. The LOW BATTERY alarm indicator comes on several seconds after battery power falls below approximately 4 volts. When lit, LOW BATTERY means that battery power is inadequate to sustain, for one hour, the audible alarm and information in battery-backed memory.

If the LOW BATTERY alarm indicator is illuminated, you should:

- provide alternate ventilatory support for the patient,
- monitor the LOW BATTERY indicator while running the ventilator for two hours with no patient connected,
- press <ALARM RESET> to run a battery check. If the indicator comes back on several seconds later, replace both batteries.

Refer to Figure 4-11 for how to replace batteries. (Refer to the Storage section in this chapter for the effects of battery replacement on ventilator settings.) Be sure to connect the batteries with the correct polarity. If the batteries are incorrectly connected, they will not slide back into the ventilator.

If the LOW BATTERY indicator comes back on after you have replaced both batteries and pressed <ALARM RESET>, contact a service technician.

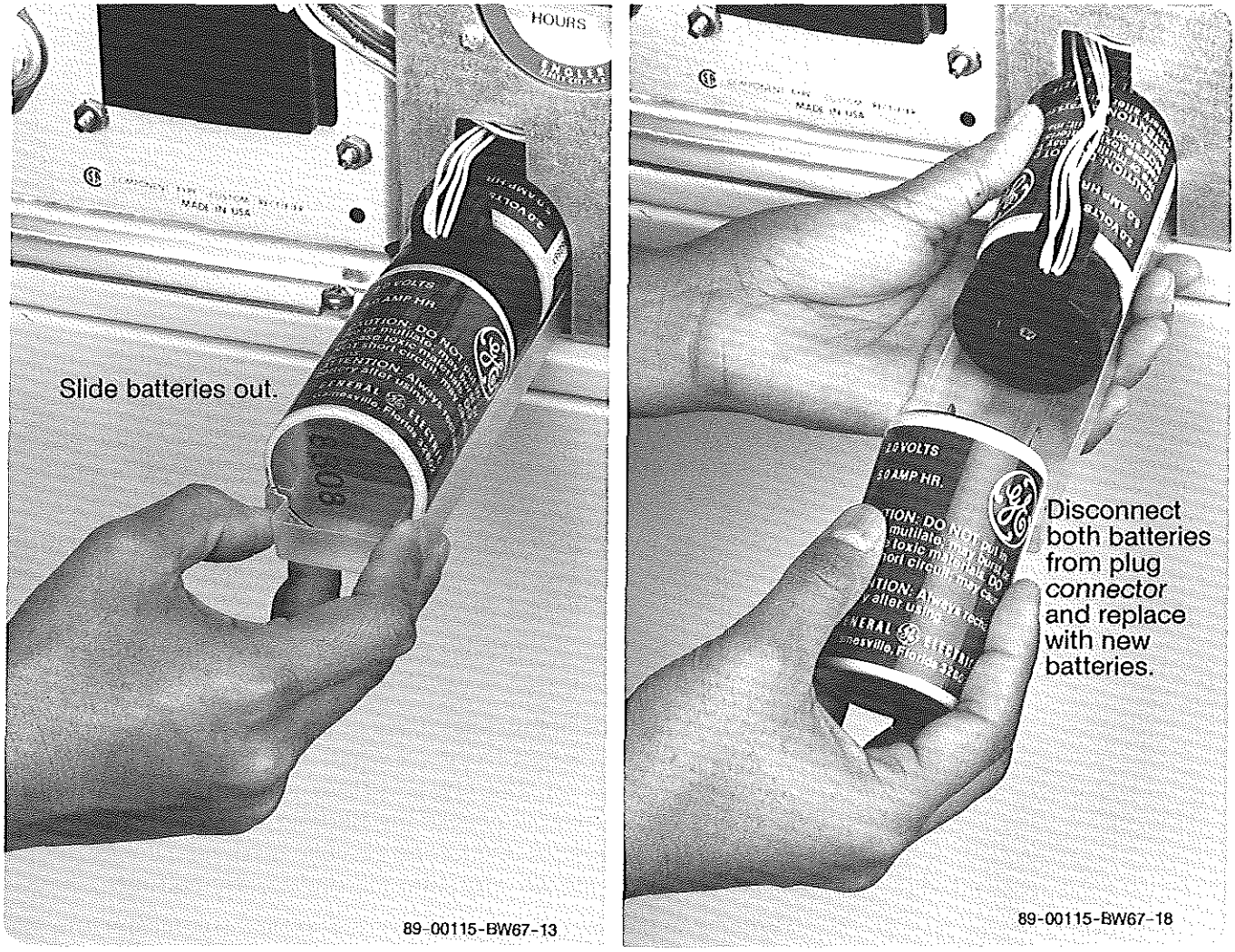


Figure 4-11. Replacing Batteries

Ongoing Checks in Ventilator Maintenance

Ongoing checks, combined with the ventilator's self-diagnostic tests, assist the operator in verifying the ventilator's performance. These checks run continuously during normal operation and are able to detect system errors and system faults. (A system error is an electronics failure that may not jeopardize the ability to deliver gas to a patient. A system fault jeopardizes the ventilator's ability to deliver gas.)

If the ongoing checks detect three system errors within 24 hours, the Back Up Ventilator mode is automatically initiated and an audible alarm sounds.

Detection of criteria indicating a system fault shuts down ventilator function. When this occurs, the safety valve opens, the VENTILATOR INOPERATIVE indicator lights, the audible alarm sounds, the error is recorded in batter-backed memory, and an error message appears. Turn the ventilator off then on to run POST and EST to further diagnose the problem.

When a system error occurs, the audible alarm sounds, the error is recorded in battery-backed memory, and POST automatically runs. Turn the ventilator off then on to run EST to further diagnose the problem.

Storage

If the ventilator is stored for more than 200 days, the following precautions should be taken:

- Be sure that the temperature and humidity of the storage site fall within the ranges specified in the features and specifications table in Chapter 1.
- Avoid storage conditions that may promote buildup of static charge. This includes, for example, storing the ventilator on insulated material. Static buildup may damage the microprocessor electronics.
- Remove the internal batteries before storage. (Replace the internal batteries before using the ventilator again.)

The expected life of the batteries is 200 days when the ventilator is left unplugged. If you turn on the ventilator after it has been unplugged for an extended period, the LOW BATTERY alarm may come on. If the indicator does illuminate, charge the batteries for 4 hours by leaving the ventilator plugged in and turned on (with no patient connected). If LOW BATTERY is still on after 4 hours, replace the batteries.

Whenever battery voltage becomes low while the ventilator is turned off, it is possible that information may be lost from battery-backed memory. Should such loss occur, it is detected through POST and the ventilator replaces the lost values with factory-preset values. Before connecting the ventilator to a patient, review all ventilator settings, adjusting them as necessary.

Repacking

If it is necessary to ship the ventilator for any reason, try to use the original packing materials. If these materials are not available, you can order a repacking kit:

- Stand-alone ventilator, P/N 4-015241-00,
- Ventilator with compressor pedestal attached, P/N 4-015240-00, or
- Compressor/pedestal packed separately, P/N 4-015242-00.

Instructions for repacking are provided with these kits and in the *7200 Series Service Manual* (P/N 4-031052-00).

Repairs

This chapter describes some of the repairs an operator may perform to ensure proper ventilator function. For repairs not included in this chapter, see the *7200 Series Microprocessor Ventilator Service Manual.*

Puritan-Bennett offers a biomedical engineering technician program to train your technical service staff. Through its nationwide service facilities, Puritan-Bennett also offers preventive maintenance on a contract arrangement.

Contact your Puritan-Bennett representative for details concerning these services and programs.

Replacement Parts

The following figures show replacement parts that may be ordered from Puritan-Bennett.

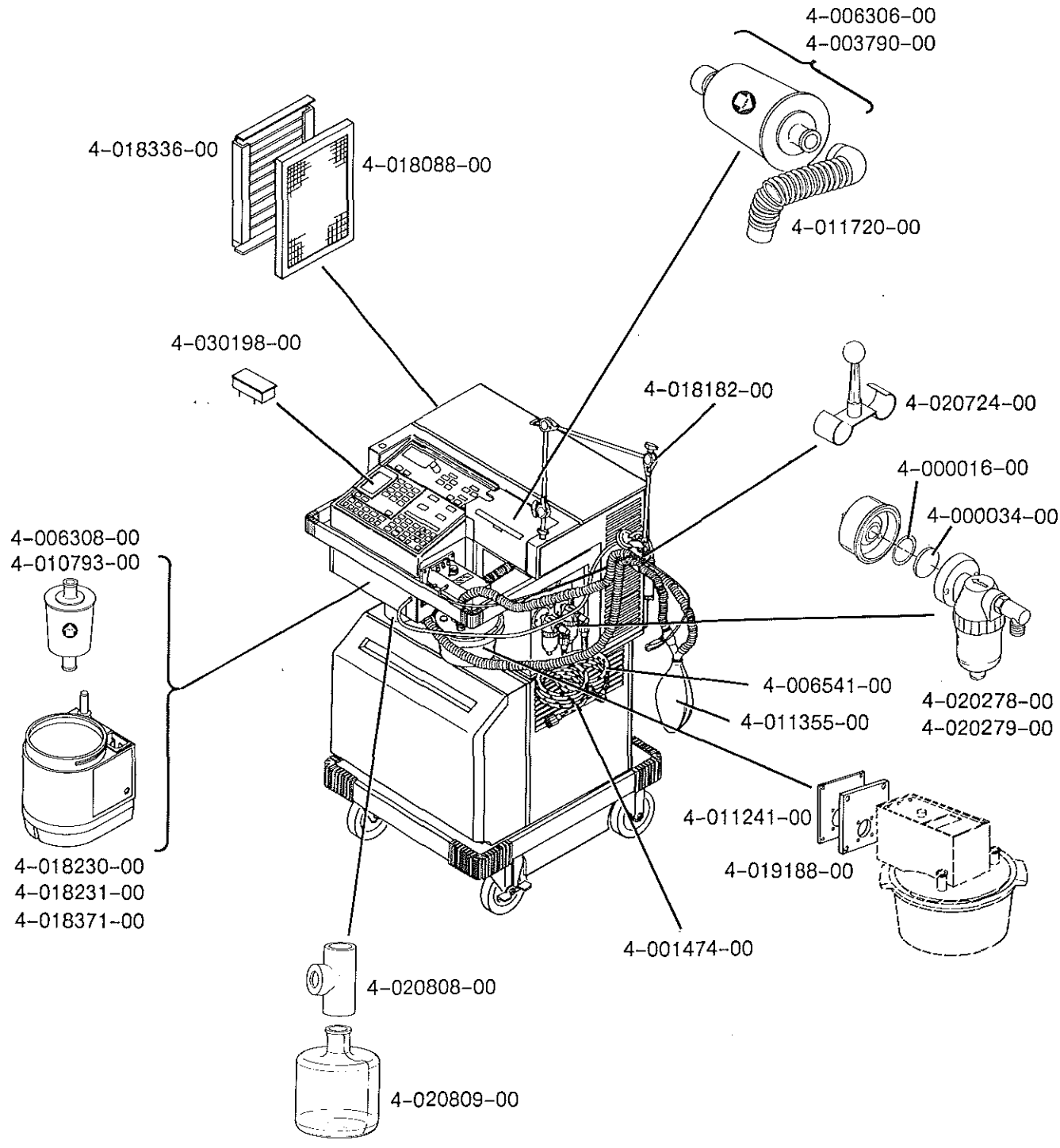
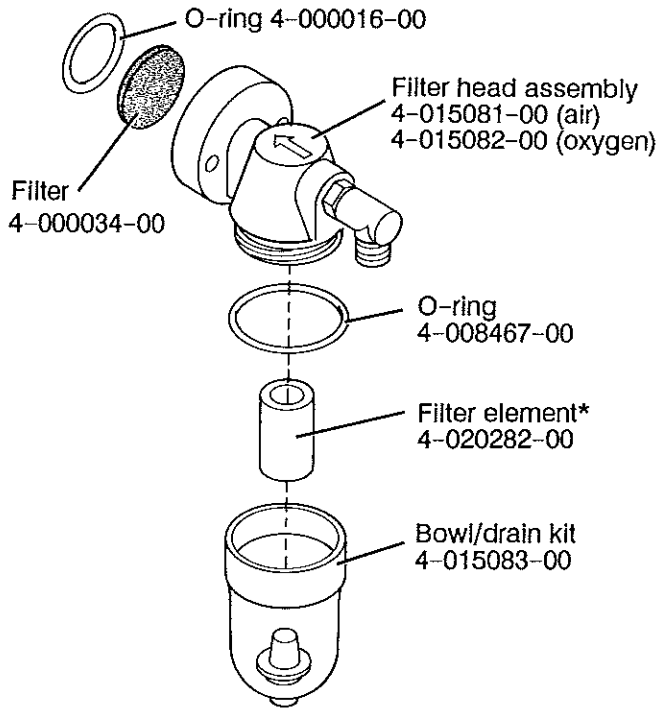


Figure 4-12. Replacement Parts for the 7200ae Ventilator

Table 4-4. Replacement Parts for the 7200ae Ventilator

Part Number	Part
4-000016-00	O-ring, air/oxygen inlet assembly
4-000034-00	Filter, air/oxygen inlet assembly
4-001375-00	Support arm (not shown)
4-001474-00	Hose, high pressure, oxygen
4-003443-00	Coupling
4-003790-00	Bacteria filter with coupling, main flow, reusable
4-003791-00	Bacteria filter, nebulizer
4-003792-00	Bacteria filter, main flow, reusable
4-006306-00	Bacteria filter, main flow, OmniFilter
4-006308-00	Bacteria filter with coupling, main flow, OmniFilter
4-006541-00	Hose, high pressure, air
4-010793-00	Bacteria filter, exhalation, Single-Patient Use
4-011241-00	Gasket, humidifier mounting
4-011355-00	Test lung
4-011720-00	Tube, from filter to humidifier
4-018088-00	Filter, electronics compartment cooling fan
4-018182-00	Flex arm, with flexible tip
4-018230-00	Heater, bacteria filter, bottom-loading, 115 V
4-018231-00	Heater, bacteria filter, bottom-loading, 230 V
4-018336-00	Panel, removable louver
4-018371-00	Heater, bacteria filter, bottom-loading, 100 V
4-019188-00	Mounting plate, humidifier
4-020278-00	Water trap and filter assembly, high pressure O_2 (see Figure 4-13 or Figure 4-14 for details)
4-020279-00	Water trap and filter assembly, high pressure air (see Figure 4-13 or Figure 4-14 for details)
4-020724-00	Tube hanger
4-020808-00	Tee adapter, collector vial (simplified circuit)
4-020809-00	Collector vial (simplified circuit)
4-022125-00	Parts List, 7200 Series (not shown)
4-022300-00	Operator's Manual, 7200ae Ventilatory System (not shown)
4-030198-00	Lamp, alarm summary display (Basic keyboard only)
4-031052-00	Service Manual, 7200 Series (not shown)
--	Patient service circuit (see Table 4-5 for details)



***CAUTION** - Replace the filter element each time the bowl is removed. The filter element is pressed into place and when removed, it remains compressed. If the element is reused, filtering efficiency is reduced.

Figure 4-13. Replacement Parts for Gas Supply Water Trap and Filter Assembly (with spring-type drain)

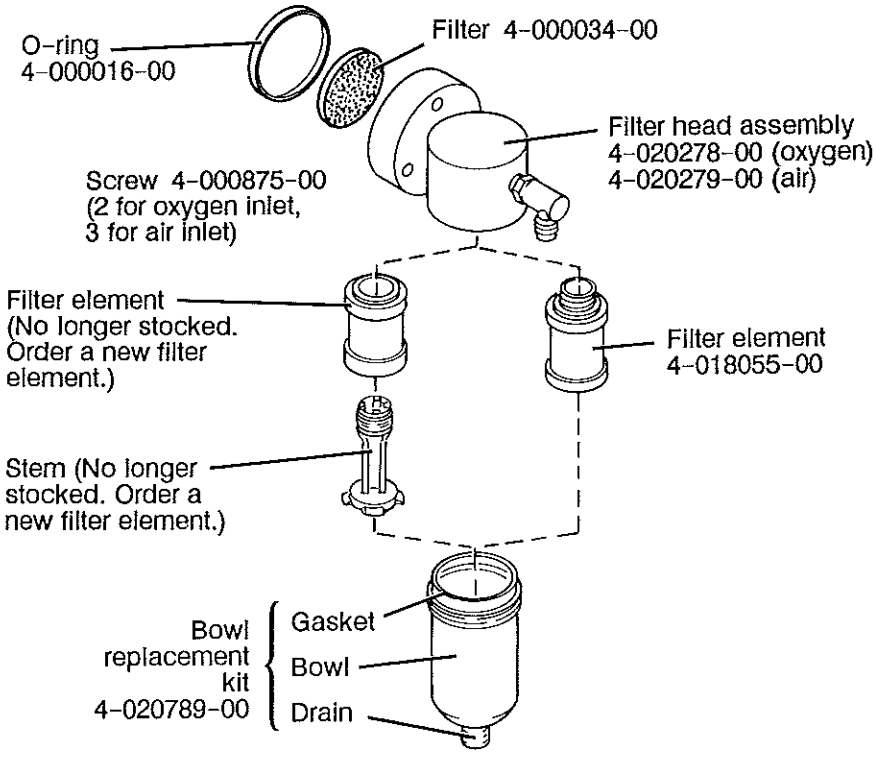


Figure 4-14. Replacement Parts for Gas Supply Water Trap and Filter Assembly (with screw-type drain)

Table 4-5. Accessories List

Part Number	Part
4-001963-00	Cascade I Humidifier (115V)
4-007900-00	Humidifier temperature alarm
4-009366-00	Cascade II Humidifier (115V)
4-019715-00	O_2 Monitor with reusable sensor/cable assembly (includes Monitor (4-019701-00), sensor/cable assembly (4-011410-00), gel (4-004157-00), and operating instructions (4-019705-00)
4-019330-00	O_2 Monitor ventilator mounting bracket
4-019741-00	O_2 Monitor universal mounting bracket
4-016902-00	Simplified patient service circuit (disposable)
4-018062-00	Simplified patient service circuit (disposable), with in-line water traps and nebulizer
6-003030-00	Simplified patient service circuit (disposable); integral temperature coupling without nebulizer
4-018011-00	Simplified patient service circuit (reusable); removable temperature coupling
4-018017-00	Simplified patient service circuit (reusable); integral temperature coupling
--	Printer (consult your Puritan-Bennett representative to order)
--	7202 Display (consult your Puritan-Bennett representative to order)

7200ae Ventilator Maintenance Record

Ventilator Serial Number _____

Hospital Identification Number _____

Recommended Hours of Patient Use	Actual Hours of Patient Use	Preventive Maintenance Performed	Maintenance Provider	Date Maintenance Performed
2,500 hours		☐ Ventilator ☐ Compressor		
5,000 hours		☐ Ventilator ☐ Compressor		
Other services performed				
7,500 hours		☐ Ventilator ☐ Compressor		
10,000 hours		☐ Ventilator ☐ Compressor		
Other services performed				
12,500 hours		☐ Ventilator ☐ Compressor		
15,000 hours		☐ Ventilator ☐ Compressor		
Other services performed				
17,500 hours		☐ Ventilator ☐ Compressor		
20,000 hours		☐ Ventilator ☐ Compressor		
Other services performed				

7200ae Ventilator Maintenance Record

Ventilator Serial Number _____

Hospital Identification Number _____

Recommended Hours of Patient Use	Actual Hours of Patient Use	Preventive Maintenance Performed	Maintenance Provider	Date Maintenance Performed
22,500 hours		☐ Ventilator ☐ Compressor		
25,000 hours		☐ Ventilator ☐ Compressor		
Other services performed				
27,500 hours		☐ Ventilator ☐ Compressor		
30,000 hours		☐ Ventilator ☐ Compressor		
Other services performed				
32,500 hours		☐ Ventilator ☐ Compressor		
35,000 hours		☐ Ventilator ☐ Compressor		
Other services performed				
37,500 hours		☐ Ventilator ☐ Compressor		
40,000 hours		☐ Ventilator ☐ Compressor		
Other services performed				

Ventilator Self-Tests 5

Introduction

This chapter describes the self-tests for the 7200ae Ventilator: Power-On Self-Test (POST) and Extended Self-Test (EST). These self-tests check overall ventilator function by testing specific functions of ventilator subsystems. EST has two forms: Quick Extended Self-Test (QUEST), and Total Extended Self-Test (TEST).

Power-On Self-Test (POST) Overview

The Power-On Self-Test (POST) runs for three reasons: when the ventilator is switched on, when QUEST or TEST is run, or when Ongoing Checks detect a system error (discussed at the end of this chapter). POST verifies that the electronic subsystem functions correctly and is capable of detecting errors in microprocessor electronics.

POST lasts about 5 seconds. During POST, the ventilator's safety valve opens, the message [POWER-ON SELF-TEST] appears in the message window, and the rest of the keyboard display panel blanks out. These return to normal when POST completes successfully.

An error message may appear in the message window when a test fails during POST. The message has the form [WXYZ ERR], where WXYZ represents the four numbers in an error code. Press the <++> key to see a short information message about the error. Note the error number and message and provide them to service personnel.

NOTE – The message [1401 ERR] indicates that battery-backed memory (BBR) has been reinitialized with default settings. The operator should review all settings immediately.

See the section EST Error Messages and Error Codes in this chapter for an explanation of other error codes and error types.

WARNING – *If the ventilator fails POST, the Back Up Ventilator mode (an emergency mode of ventilation) initiates automatically. Replace the ventilator as soon as possible. Have the ventilator serviced before using on patients.*

Extended Self-Test (EST) Overview

WARNING – *Never initiate EST while a patient is connected to the ventilator. The ventilator does not provide normal ventilatory support during EST. A patient connected to the ventilator can be injured by airway pressures or gas flow controlled by EST (see Safety Features in Chapter 2).*

Both types of EST are operator-initiated. Quick Extended Self-Test (QUEST) should be performed every time the patient service circuit is changed. Total Extended Self-Test (TEST) is a thorough self-diagnostic which should be performed as part of ventilator maintenance. EST cannot be run if POST has failed and the ventilator is operating in the Back Up Ventilator mode.

QUEST is a short diagnostic, approximately 2 minutes long, that primarily tests the patient service system for leaks and calculates compliance and area ratio values. These calculations are used by the microprocessor in definition of patient breaths. QUEST also tests the ventilator's battery-backed memory (BBR).

TEST is a detailed check of major ventilator components and subsystems. TEST takes from 3 to 5 minutes, depending upon operator experience and ventilator configuration.

An oxygen supply and high pressure air supply are required to run TEST. For details on running QUEST or TEST, refer to the Running EST section later in this chapter.

Both forms of EST perform critical and noncritical tests. Noncritical tests check components and operations whose failure may not compromise patient safety. Critical tests check components and operations that would compromise patient safety if they failed. See Table 5-6 (EST Test Sequences) at the end of this chapter for a listing of critical and noncritical tests. QUEST and TEST use identical criteria to determine pass/fail status when they perform the same test.

EST and Digital Displays

The ventilator's digital displays are active during EST. A critical test failure during EST lights the red VENTILATOR ALARM indicator in the ventilator's alarm summary display. A noncritical test failure during EST lights the yellow CAUTION indicator. During EST, the NORMAL indicator remains lit until an error is detected; if NORMAL is lit at the end of EST, then no errors were detected. Figure 5-1 summarizes these displays and their meanings.

Running EST

1. Press the <EST> button on the utility panel to request EST. The prompt [START EST–ENTER] appears in the message window.
2. Press <ENTER> if you want to continue the self-test. The prompt [PAT TUBING OFF–ENTER] appears.
3. Press <ENTER> after verifying that a patient is not connected to the ventilator. The ventilator then runs POST.
4. When POST completes, the prompt [QUICK EST] appears. To run QUEST, press <ENTER>. To run TEST, press <++> and then <ENTER>.

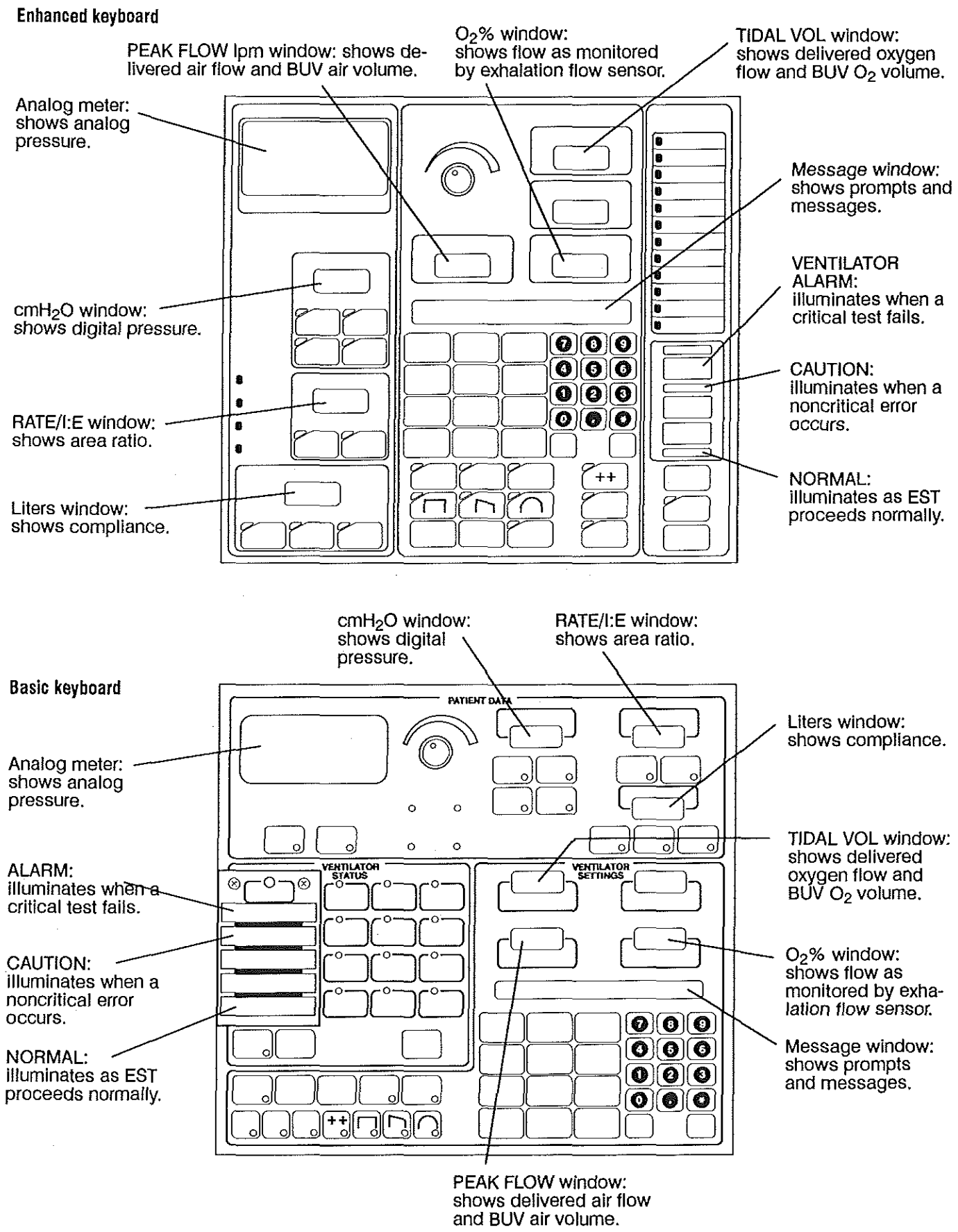


Figure 5-1. Digital Displays & Indicators Active During EST

An EST request can be canceled in three ways:

- pressing <ALARM RESET> or <CLEAR> after pressing <EST>.
- not responding to the prompts [START EST–ENTER] or [PAT TUBING OFF–ENTER] within 18 seconds after they are displayed.
- pressing any ventilator status or setting key. Pressing <EST> again requests EST.

NOTE - Once the test sequences have begun, the only way to stop EST is to deliberately fail a step when the ventilator requests your response. (For example, at [521 BLOCK WYE], you can ignore the prompt until the message times out.) You will then see an error message and [EST COMPLETE] or [EST FAIL]. Press <ALARM RESET> and <ENTER> to override the error and stop EST.

5. During some EST test steps, you are prompted to act or respond. If you don't press <ENTER> or <CLEAR> in the time allotted (usually 15 seconds), the test step fails.
   - Press <ENTER> after you complete the action described in the message window. For example, [521 BLOCK WYE] means that you should block the patient wye. Then press <ENTER> to confirm the action.
   - Respond to the prompts [591 NEB ATTACH/] and [601 COMPR ATTACH/] by pressing <ENTER> if the equipment is attached or by pressing <CLEAR> to skip the tests if the equipment is not attached. Performing these tests without a nebulizer or compressor causes EST to fail.
   - At EST test step 583 you are prompted to set PEEP to 35, 30, 20, 15, 10, 5, and 0 cmH_2O. Respond to each prompt by turning the PEEP/CPAP control knob until the PEEP value (displayed in the cmH_2O digital window) equals the specified amount. The area ratio value is calculated while PEEP is lowered. Three short beep tones signal you to turn the knob and a longer string of beep tones notifies you to fine-tune the knob to the desired setting.
6. After EST successfully completes, do not turn off the ventilator when [EST PASS] is displayed. Allow the ventilator time to start ventilation automatically before turning it off. Turning it off before ventilation begins causes [RUN EST–DO NOT USE] to appear the next time the ventilator is turned on.

NOTE - Failure to connect oxygen can cause EST to end in an EST FAIL state.

Operator errors during EST can cause two error messages: [INVALID KEY] or [OPERATOR RESPONSE TIMED OUT. PLEASE RESPOND TO THE PROMPT]. [INVALID KEY] means that you pressed the wrong key in response to a prompt. Press the correct key to continue EST. Pressing an incorrect key twice causes [WXYZ ERR] to be displayed. If this happens, press <*> twice, then <ENTER> to repeat the test.

If the [TIMED OUT] message appears, you may not have entered the requested information or have taken the correct action within the

allotted time. [TIMED OUT] may also be displayed if the ventilator cannot respond correctly to an action. For example, [TIMED OUT] displayed when setting PEEP to zero may mean the PEEP circuit cannot achieve a PEEP of 0, not that you responded incorrectly to the prompt. If [TIMED OUT] is displayed, repeat the test. Make the correct response within the allotted time to verify that a slow response did not cause the message.

Power Loss During EST

If the ventilator is turned off or loses power during EST, the prompt [RUN EST–DO NOT USE] is displayed when power is restored. The audible alarm sounds and the ventilator goes into back up ventilator mode. The ventilator cannot be used until QUEST or TEST is run successfully and passed or overridden.

EST Leak Tests and Patient Safety

EST test steps 541 and 542 test the patient tubing for leaks. Failure to pass step 541 indicates a significant leak exists. Step 541 pressurizes the patient tubing system to 90 cmH_2O at an air flow of 10 Lpm within 30 seconds. QUEST ends in an EST COMPLETE state if this test step is failed. A patient could potentially be placed at risk by excessive leakage if QUEST is overridden after failing test step 541.

> ***WARNING*** – *Puritan-Bennett urges medical departments to review the implications of using a ventilator that fails test step 541 or 542. Puritan-Bennett recommends establishing a medical department protocol that defines the conditions under which ventilator usage is acceptable.*

Troubleshoot the patient service system if test 541 is failed. Locate the leak and correct it. If the leak cannot be corrected, assess the degree of risk to the patient before beginning ventilation.

After test step 541 is passed, test step 542 checks the patient tubing for a leak of 15 cmH_2O within 10 seconds. A message is displayed if a leak in excess of the value is detected. If a leak greater than 15 cmH_2O within 10 seconds is detected, QUEST and TEST end in an EST COMPLETE state.

Assess the degree of risk to a patient before beginning ventilation if test step 542 fails. The ventilator's ability to achieve desired peak airway pressure and tidal volumes may be compromised. The ventilator may not be able to maintain selected PEEP values, which could cause autocycling.

EST Start/End Displays and Operator Actions

The following table lists QUEST and TEST messages, the keys that you can press (at the beginning or end of EST), and the ventilator responses to those keys.

Table 5-1. QUEST and TEST Start/End Messages and Operator Actions

Message	Key Pressed	System Response
[QUICK EST]	<ALARM SILENCE>	Display [QUICK EST].
	<ALARM RESET>	Do not begin test sequences. Display [EST COMPLETE] and [OVERRIDE–ENTER].
	<ENTER>	Begin the first QUEST test sequence.
	<++>	Display [TOTAL EST].
[TOTAL EST]	<ALARM SILENCE>	Display [QUICK EST].
	<ALARM RESET>	Do not begin test sequences. Display [EST COMPLETE] and [OVERRIDE–ENTER].
	<ENTER>	Begin the first TEST test sequence.
[WXYZ ERR]	<ALARM SILENCE>	Display [QUICK EST].
	<ALARM RESET>	Display [EST COMPLETE] and [OVERRIDE–ENTER].
	<*>	Repeat the last test sequence. (Press <*> twice to repeat a failed step.)
	<++>	Display [TOTAL EST].
[EST PASS]		Normal ventilation begins
[OVERRIDE–ENTER]	<ENTER>	Bypass EST and begin conditional ventilation. Record the bypass condition in battery-backed memory.
	Any key except <ENTER>	To the beginning of the EST version.

EST Features

Here are some helpful procedures you can perform during QUEST or TEST.

Figure 5-2 shows common features and the keys used to access them.

1. Repeat a test sequence after a test step failure:
   - Press <*> twice to back up and return to the beginning of the failed two-digit test (for example, to return to the beginning of test 54 after failing test step 541). You will see the message [REPEAT TEST] then the number of the test to be executed.
   - Press <ENTER> to repeat the test currently displayed. Press <*> once for each test you want to back up. Normal ventilation begins at the end of EST if failed tests are repeated and passed.
2. Display the results of the last EST version (QUEST or TEST) run:
   - Press <0> after [QUICK EST] is displayed. The date and time of the last QUEST or TEST, values for patient circuit leakage and compliance, and the area ratio of the exhalation valve are displayed. The conclusion state (passed or bypassed) is also displayed.
   - If a 7202 Display is installed, press the <EST> button and <ENTER> to view the Quick EST or Total EST screen.

3. Stop a scrolling error message:

   - Press <ENTER> after an error message has begun scrolling to stop the message and display the error code for the failed test step.

4. Repeat QUEST or TEST from the beginning:

   - Press <ALARM SILENCE> after an EST fail state, a test failure, or during error review. [QUICK EST] is displayed. Press <ENTER> to begin QUEST or press <++> and then <ENTER> to begin TEST.

5. Display the error codes and corresponding date and time stamps for the last six errors detected:

   - Press a numeric key from <1> to <6> after [QUICK EST] is displayed. Press <1> to show the most recent error and <6> to show the least recent error.

   - If a 7202 Display is installed, press the <EST> button and <ENTER> to view the Quick EST or Total EST screen (all six error codes are displayed).

6. Read the measured leak value in cmH_2O when measured patient circuit leakage is out of limits.

   - Look at the message window at the end of test step 542 (leak test).

7. Read the calculated values for compliance and area ratio:

   - Look at the message window during test step 572 (display of calculated compliance values) to see the compliance value. Look at the message window at the end of the test step 583 (lowering PEEP from 35 cmH_2O to 0 cmH_2O) to see the calculated average exhalation valve area ratio value.

8. Override [EST COMPLETE] or [EST FAIL] state:

   - Press <ENTER> when [OVERRIDE–ENTER] is displayed after [EST COMPLETE] or [EST FAIL] and their accompanying messages have been displayed.

9. Read the name of the test currently being run.

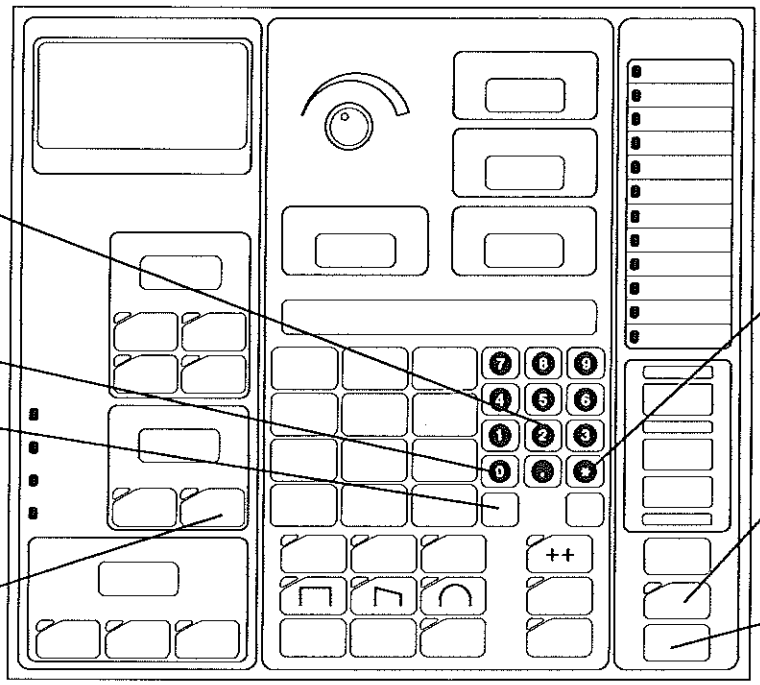
   - Look at the message window while QUEST or TEST is running.

10. See the ventilator's software number, software revision number, and installed options code:

    - Press <I:E RATIO> after [QUICK EST] is displayed. The version and option code appear in the message window like [REV NNNNN-85A ZZZ]. NNNNN is the software number, 85A is the software revision level, and ZZZ is a code that represents options installed in the ventilator.

    - Press <LAMP TEST> to see the software revision level, which can be done anytime, not just in conjunction with EST.

Enhanced keyboard



Keys <1> to <6>
Press to display EST error codes; <1> for most recent, <6> for least recent.

<0>
Press after [QUICK EST] is displayed to display results of last EST run.

<ENTER>
Press to stop a scrolling message; press to confirm an action (e.g. unblocking patient wye); press to override last fail state.

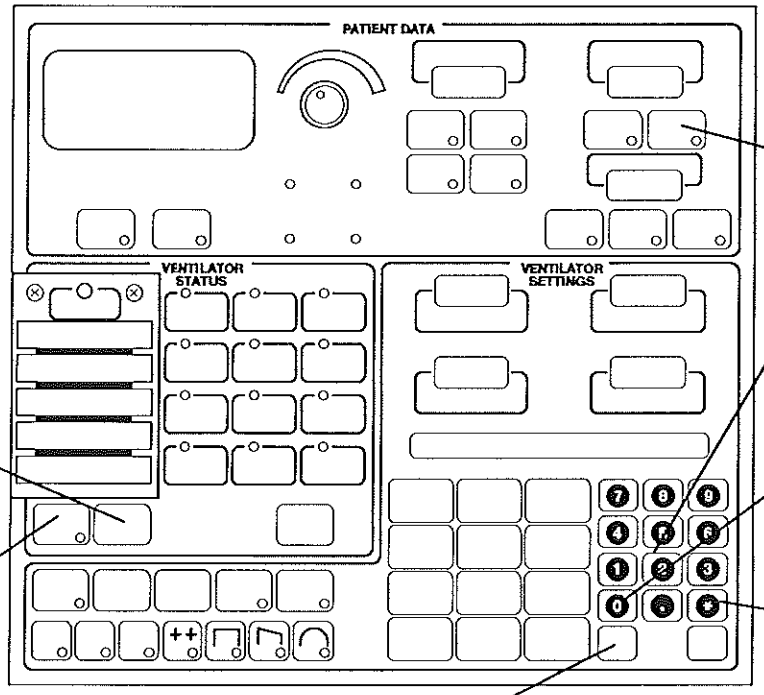
<I:E RATIO>
Press to see software part number, revision, and options code.

<*>
Press twice to back up one test sequence when a test step fails.

<ALARM SILENCE>
Press to repeat EST after an EST fail state, test failure, or during error review.

<ALARM RESET>
Press after a test step fails to stop EST.

Basic keyboard



<I:E RATIO>
Press to see software part number, revision, and options code.

Keys <1> to <6>
Press to display EST error codes; <1> for most recent, <6> for least recent.

<0>
Press after [QUICK EST] is displayed to display results of last EST run.

<*>
Press twice to back up one test sequence when a test step fails.

<ALARM RESET>
Press after a test step fails to stop EST.

<ALARM SILENCE>
Press to repeat EST after an EST fail state, test failure, or during error review.

<ENTER>
Press to stop a scrolling message; press to confirm an action (e.g. unblocking patient wye); press to override last fail state.

Figure 5-2. EST Features

Running QUEST

To run QUEST:

1. Press the <EST> button on the utility panel and follow the prompts. When POST is passed, [QUICK EST] is displayed.
2. Press <ENTER> to run QUEST.

Table 5-2. QUEST Procedure

Operator Action	Message Window and Ventilator Response	Explanation
Connect external air and oxygen supplies and turn on the ventilator.	*POST is run.*	–
Press <EST> on the utility panel.	[START EST–ENTER]	Prompts you to press <ENTER> to start EST.
Press <ENTER>.	[PAT TUBING OFF–ENTER]	Prompts operator to make certain a patient is not connected to the ventilator. The ventilator returns to previous operational state if you do not press <ENTER> within 10 seconds or if you press any other key.
Press <ENTER> to initiate POST.	[POWER-ON SELF-TEST] [QUICK EST] is displayed after POST is passed.	POST runs (approximately 5 seconds).
Press <ENTER> to initiate QUEST.	[51 TEST BBR]	Start of battery-backed memory (BBR) *test group.*
	[511 TEST BBR]	Verifies BBR using a variable pattern type test.
	[512 TEST BBR]	Verifies BBR by performing a checksum.
	[52 AUTOZERO]	Start of test group to autozero pressure transducers.
	[521 BLOCK WYE]	*If <ENTER> is not pressed within 30 seconds,* [OPERATOR RESPONSE TIMED OUT. PLEASE RESPOND TO THE PROMPT] appears. Repeat the test by pressing <✻> twice, then <ENTER>.
Block the patient wye with a #2 rubber stopper. Then press <ENTER>.	[521 TESTING.....]	The PEEP/CPAP pressure sensor is zeroed.
	[522 TESTING.....]	The absolute pressure sensor is calibrated.
	[523 TESTING.....]	The differential pressure sensor is zeroed.
	[524 CONNECT O2] (if a high pressure oxygen supply is not connected)	
If oxygen has not been connected, connect oxygen and press <ENTER>.		If oxygen is not connected and <ENTER> pressed within 30 seconds, the [TIMED OUT] messge appears. Repeat the test by pressing <✻> twice, then <ENTER>.

Table 5-2. QUEST Procedure (continued)

Operator Action	Message Window and Ventilator Response	Explanation
If air has not been connected and no compressor is attached, connect air and press <ENTER>.	[525 CONNECT AIR] (if the unit does not have a compressor and an air supply is not connected)	If air is not connected and <ENTER> pressed within 30 seconds, the [TIMED OUT] message appears. Repeat the test by pressing <*> twice, then <ENTER>.
If PEEP is not set to 0, turn the PEEP/CPAP knob counter-clockwise. Stop and press <ENTER>.	[531 SET PEEP=0] appears if PEEP has not been set to 0.	
	[53 CHECKING FOR PT]	Start of steps to ensure that a patient is not connected to the ventilator.
	[531 CHECKING FOR PT]	Checks for a patient connected to the ventilator.
	[532 CHECKING FOR PT]	Verifies no patient is connected by passing an air flow of 10 Lpm through the patient circuit.
	[533 CHECKING FOR PT]	Verifies no patient is connected by pressurizing to 30 cmH_2O.
	[534 CHECKING FOR PT]	Verifies no patient is connected by monitoring pressure.
	[535 CHECKING FOR PT]	Crosschecks absolute and differential pressure.
If test 541 fails, inspect patient circuit; repeat the test by pressing <*> twice, then <ENTER>.	[54 LEAK TEST]	Start of leak test.
	[541 LEAK TEST]	Establishes an air flow of 10 Lpm and pressurizes the patient tubing system to 90 cmH_2O.
	If system pressure does not attain 90 cmH_2O within 30 seconds, this message scrolls: [THIS TEST HAS DETECTED A LEAK GREATER THAN 15 CMH2O OR HAS FAILED TO PRESSURIZE TO 90 CMH2O. PLEASE CHECK THE PATIENT CIRCUIT]. [5411 CANT PRESSURIZE] appears after the scrolling message.	***WARNING*** – *A life-threatening situation could occur if a pressure of 90 cmH_2O cannot be obtained. Trouble-shoot the patient service circuit if test step 541 is failed. Locate the leak and correct it. Assess degree of risk to a patient before beginning ventilation.*

Table 5-2. QUEST Procedure (continued)

Operator Action	Message Window and Ventilator Response	Explanation
If test 542 fails, inspect the patient service circuit; repeat the test by pressing <✻> twice, then <ENTER>.	[542 LEAK TEST] If leakage exceeding 15 cmH_2O within 10 seconds is detected, the following message scrolls: [THIS TEST HAS DETECTED A LEAK GREATER THAN 15 CMH2O OR HAS FAILED TO PRESSURIZE TO 90 CMH2O]. [5421 XX.X CMH2O LEAK], where X *is a digit from 0 to 9, ap*pears after the scrolling message.	Checks for leaks at 90 cmH_2O by monitoring patient tubing system pressure for 10 seconds. Checks for a pressure drop of more than 15 cmH_2O within 10 seconds. ***WARNING** – Assess the degree of possible risk to a patient before beginning ventilation if test step 542 is failed. The ventilator's ability to achieve the desired peak airway pressure and tidal volume may be compromised. The ventilator may not be able to maintain selected PEEP values (this could cause autocycling).*
	[543 LEAK TEST]	Checks differential and absolute pressure sensors at 90 cmH_2O.
	[55 AUTOZERO PSOLS] [557 AUTOZERO PSOLS]	Start of PSOLs check. Autozeros O_2 and air PSOLs at 1.0 Lpm.
	[57 COMPLIANCE] [571 COMPLIANCE] [572 COMPL=XX.X] (where X is a digit from 0 to 9)	Start of compliance/safety valve check. Test safety valve in the open state. Displays compliance values calculated at 30, 60, and 85 cmH_2O. If the calculated compliance is not within limits, the following message scrolls: [THE COMPLIANCE CALCULATION IS OUT OF RANGE. A DEFAULT COMPLIANCE OF 0.1 WILL BE USED]. Ensure that the patient wye is blocked. Check or replace the patient service circuit. Repeat the test by pressing <✻> twice, then <ENTER>. If the test fails again, have the ventilator serviced before using it.

Table 5-2. QUEST Procedure (continued)

Operator Action	Message Window and Ventilator Response	Explanation
	[58 AREA RATIO]	Start of area ratio and PEEP test.
	[581 AREA RATIO]	Cross-checks PEEP/CPAP pressure sensor against differential pressure sensor.
	[582 AREA RATIO]	Verifies that PEEP/CPAP pressure sensor begins at 0 cmH_2O.
Adjust the PEEP/CPAP control knob to the values requested by message window.	[583 SET PEEP = 35]	This message appears and beep tones sound to prompt the operator to turn the knob until 35 appears in the cmH_2O window. As the displayed value comes close to the desired setting, a long series of beep tones sounds and [PLEASE PAUSE] appears in the message window. When the desired setting is nearly reached, the display locks in that value and will not allow further adjustment until the next prompt.
	[583 SET PEEP = 30]	Turn knob until cmH_2O window shows 30 cmH_2O (± 5%).
	[583 SET PEEP = 20]	Turn knob until cmH_2O window shows 20 cmH_2O (± 5%).
	[583 SET PEEP = 15]	Turn knob until cmH_2O window shows 15 cmH_2O (± 5%).
	[583 SET PEEP = 10]	Turn knob until cmH_2O window shows 10 cmH_2O (± 5%).
	[583 SET PEEP = 5]	Turn knob until cmH_2O window shows 5 cmH_2O (± 5%).
	[583 SET PEEP = 0]	Turn knob until cmH_2O window shows 0 cmH_2O (± 5%).
	[A/R AVG = X.XX] (where X is a digit from 0 to 9).	Displays average area ratio value.
	[EST PASS] **OR**	No errors were detected. Normal ventilator operation begins automatically. Do not turn off the ventilator until ventilation begins, otherwise an error message appears the next time the ventilator is turned on.
	[EST COMPLETE—EST HAS FINISHED AND HAS DETECTED A NONCRITICAL ERROR. PERFORMANCE MAY BE AFFECTED OR NONCRITICAL SUBSYSTEMS MAY NOT WORK. ASSESS RISK/BENEFIT BEFORE USING THIS UNIT].	A noncritical error was detected.
Press <ENTER> to stop the scrolling message	[EST COMPLETE]	The [EST COMPLETE] message disappears after a few seconds.

Table 5-2. QUEST Procedure (continued)

Operator Action	Message Window and Ventilator Response	Explanation
	[OVERRIDE–ENTER]	Prompts operator to press <ENTER> to override EST. Pressing any other key repeats EST. Overriding bypasses EST. This abnormal conclusion state, EST Bypassed, is logged into battery-backed memory. [EST BYPASSED] is displayed when viewing the last EST results until EST is rerun again and passed.
WARNING – *Make certain that overriding [EST COMPLETE] does not place a patient at risk before using the ventilator.* Press <ENTER> to override EST and begin conditional ventilation.	Ventilation begins. **OR**	Ventilation is conditional.
	[EST FAIL–EST HAS FINISHED AND HAS DETECTED A CRITICAL ERROR. WE RECOMMEND THAT THIS UNIT NOT BE USED UNTIL SERVICED. OVERRIDE MAY PLACE PATIENT AT RISK].	A critical error has been detected.
Press <ENTER> to stop the scrolling message.	[EST FAIL]	The [EST FAIL] message disappears after a few seconds.
	[OVERRIDE–ENTER]	Prompts operator to press <ENTER> to override EST. Pressing any other key repeats EST.
WARNING – *Do not use a ventilator that fails EST without first verifying its operational readiness. Use methods independent of EST. Then determine that a patient will not be placed at risk.* Press <ENTER> to override EST and begin ventilation.	Ventilation begins.	Ventilation is conditional.

Running TEST

To run TEST:

1. Press the <EST> button on the utility panel and follow the prompts. When POST is passed, [QUICK EST] is displayed.
2. Press <++> and then <ENTER> to run TEST.

An oxygen supply and high pressure air supply are required to run TEST.

Table 5-3. TEST Procedure

Operator Action	Message Window and Ventilator Response	Explanation
Connect external air and oxygen supplies and turn on the ventilator.	POST is run.	–
Press <EST> on the utility panel.	[START EST–ENTER]	Prompts you to press <ENTER> to start EST.
Press <ENTER>.	[PAT TUBING OFF–ENTER]	Prompts operator to make certain a patient is not connected to the ventilator. The ventilator returns to previous operational state if you do not press <ENTER> within 10 seconds or if you press any other key.
Press <ENTER> to initiate POST.	[POWER-ON SELF-TEST]	POST runs (approximately 5 seconds).
	[QUICK EST] is displayed after POST is passed.	Beginning of QUEST test sequences.
Press <++> and <ENTER> to initiate TEST.	[TOTAL EST]	Beginning of TEST sequences.
	[51 TEST BBR]	Start of battery-backed memory (BBR).
	[511 TEST BBR]	Verifies BBR using a variable pattern type test.
	[512 TEST BBR]	Verifies BBR by performing a checksum.
	[52 AUTOZERO]	Start of test group to autozero pressure transducers.
	[521 BLOCK WYE]	If <ENTER> is not pressed within 30 seconds, [OPERATOR RESPONSE TIMED OUT. PLEASE RESPOND TO THE PROMPT] appears. Repeat the test by pressing <*> twice, then <ENTER>.
Block the patient wye with a #2 rubber stopper. Then press <ENTER>.	[521 TESTING.....]	The PEEP/CPAP sensor is zeroed.
	[522 TESTING.....]	The absolute pressure sensor is calibrated.
	[523 TESTING.....]	The differential pressure sensor is zeroed.
	[524 CONNECT O2] (if a high pressure oxygen supply is not connected)	
If oxygen has not been connected, connect oxygen and press <ENTER>.		If oxygen is not connected and <ENTER> pressed within 30 seconds, the [TIMED OUT] message appears. Repeat the test by pressing <*> twice, then <ENTER>.
	[525 CONNECT AIR] (if the unit does not have a compressor and an air supply is not connected)	
If air has not been connected and no compressor is attached, connect air and press <ENTER>.		If air is not connected with 30 seconds, the [TIMED OUT] message appears. Repeat the test by pressing <*> twice, then <ENTER>.

Table 5-3. TEST Procedure (continued)

Operator Action	Message Window and Ventilator Response	Explanation
If PEEP is not set to 0, turn the PEEP/CPAP knob counter-clockwise. Stop and press <ENTER>.	[531 SET PEEP=0] appears if PEEP has not been set to 0.	
	[53 CHECKING FOR PT]	Start of steps to ensure that a patient is not connected to the ventilator.
	[531 CHECKING FOR PT]	Checks for a patient connected to the ventilator.
	[532 CHECKING FOR PT]	Verifies no patient is connected by passing an air flow of 10 Lpm through the patient circuit.
	[533 CHECKING FOR PT]	Verifies no patient is connected by pressurizing to 30 cmH_2O.
	[534 CHECKING FOR PT]	Verifies no patient is connected by *monitoring differential pressure sensor.*
	[535 CHECKING FOR PT]	Crosschecks absolute and differential pressure.
	[54 LEAK TEST]	Start of leak test.
	[541 LEAK TEST]	Establishes an air flow of 10 Lpm and pressurizes the patient tubing system to 90 cmH_2O. ***WARNING*** – *A life-threatening situation could occur if a pressure of 90 cmH_2O cannot be obtained. Troubleshoot the patient service circuit if test step 541 is failed. Locate the leak and correct it. Assess degree of risk to a patient before beginning ventilation.*
If test 541 fails, inspect patient circuit; repeat the test by pressing <*> *twice, then* <ENTER>.	If system pressure does not attain 90 cmH_2O within 30 seconds, this message scrolls: [THIS TEST HAS DETECTED A LEAK GREATER THAN 15 CMH2O OR HAS FAILED TO PRESSURIZE TO 90 CMH2O. PLEASE CHECK THE PATIENT CIRCUIT]. [5411 CANT PRESSURIZE] *appears after the* scrolling message.	

Table 5-3. TEST Procedure (continued)

Operator Action	Message Window and Ventilator Response	Explanation
If test 541 fails, inspect patient circuit; repeat the test by pressing <*> twice, then <ENTER>.	[542 LEAK TEST] If leakage exceeding 15 cmH_2O within 10 seconds is detected, the following message scrolls: [THIS TEST HAS DETECTED A LEAK GREATER THAN 15 CmH2O OR HAS FAILED TO PRESSURIZE TO 90 CmH2O]. [5421 XX.X CmH2O LEAK], where X is a digit from 0 to 9, appears after the scrolling message.	Checks for leaks at 90 cmH_2O by monitoring patient tubing system pressure for 10 seconds. Checks for a pressure drop of more than 15 cmH_2O within 10 seconds. ***WARNING*** – *Assess the degree of possible risk to a patient before beginning ventilation if test step 542 is failed. The ventilator's ability to achieve the desired peak airway pressure and tidal volume may be compromised. The ventilator may not be able to maintain selected PEEP values (this could cause autocycling).*
	[543 LEAK TEST]	Checks differential and absolute pressure sensors at 90 cmH_2O.
	[55 AIR VS EXHALE]	Start of air flow sensor vs exhalation flow sensor test.
	[550 AIR VS EXHALE]	Flushes system with air.
	[551 AIR VS EXHALE]	Tests air sensor vs exhalation sensor at 0 Lpm. Displays air flow value in the PEAK FLOW lpm window and exhalation value in the O_2% window.
	[552 AIR VS EXHALE]	Tests air sensor vs exhalation sensor at 20 Lpm. Displays air flow value in the PEAK FLOW lpm window and exhalation value in the O_2% window.
	[553 AIR VS EXHALE]	Tests air sensor vs exhalation sensor at 50 Lpm. Displays air flow value in the PEAK FLOW lpm window and exhalation value in the O_2% window.
	[554 AIR VS EXHALE]	Tests air sensor vs exhalation sensor at 100 Lpm. Displays air flow value in the PEAK FLOW lpm window and exhalation value in the O_2% window.
	[555 AIR VS EXHALE]	Tests air sensor vs exhalation sensor at 120 Lpm. Displays air flow value in the PEAK FLOW lpm window and exhalation value in the O_2% window.
	[556 AIR VS EXHALE]	Tests air sensor vs exhalation sensor at 180 Lpm (wall air) or 120 Lpm (compressor). Displays air flow value in the PEAK FLOW lpm window and exhalation value in the O_2% window.
	[558 FLOWBY OFFSETS]	Establishes 10 Lpm flow through the air sensor. Displays air flow value in the PEAK FLOW lpm window and exhalation value in the O_2% window.

Table 5-3. TEST Procedure (continued)

Operator Action	Message Window and Ventilator Response	Explanation
	[559 FLOWBY OFFSETS]	Establishes 20 Lpm flow through the air sensor. Displays air flow value in the PEAK FLOW lpm window and exhalation value in the O_2% window.
	[557 AUTOZERO PSOLS]	Zeros proportional solenoids with flow rate of 1.0 Lpm. (Step 557 done out of sequence to prevent O_2 contamination from affecting calibration.)
	[56 O2 VS EXHALE]	Start of oxygen flow sensor vs exhalation flow sensor test.
	[56 O2 VS EXHALE]	Start of oxygen flow sensor vs exhalation flow sensor test.
	[560 O2 VS EXHALE]	Flushes system with oxygen.
	[561 O2 VS EXHALE]	Tests O_2 sensor vs exhalation sensor at 0 Lpm. Displays O_2 flow value in the TIDAL VOL liters window and exhalation value in the O_2% window.
	[562 O2 VS EXHALE]	Tests O_2 sensor vs exhalation sensor at 20 Lpm. Displays O_2 flow value in the TIDAL VOL liters window and exhalation value in the O_2% window.
	[563 O2 VS EXHALE]	Tests O_2 sensor vs exhalation sensor at 50 Lpm. Displays O_2 flow value in the TIDAL VOL liters window and exhalation value in the O_2% window.
	[564 O2 VS EXHALE]	Tests O_2 sensor vs exhalation sensor at 100 Lpm. Displays O_2 flow value in the TIDAL VOL liters window and exhalation value in the O_2% window.
	[565 O2 VS EXHALE]	Tests O_2 sensor vs exhalation sensor at 120 Lpm. Displays O_2 flow value in the TIDAL VOL liters window and exhalation value in the O_2% window.
	[566 O2 VS EXHALE]	Tests O_2 sensor vs exhalation sensor at 180 Lpm. Displays O_2 flow value in the TIDAL VOL liters window and exhalation value in the O_2% window.
	[567 FLOWBY OFFSETS]	Establishes 0 Lpm flow through air, O_2, and exhalation sensors. Displays O_2 flow value in the TIDAL VOL liters window and exhalation value in the O_2% window.
	[568 FLOWBY OFFSETS]	Establishes 10 Lpm flow through air and O_2 sensors. Displays O_2 flow value in the TIDAL VOL liters window and exhalation value in the O_2% window.
	[569 FLOWBY OFFSETS]	Establishes 20 Lpm flow through air and O_2 sensors. Displays O_2 flow value in the TIDAL VOL liters window and exhalation value in the O_2% window.

Table 5-3. TEST Procedure (continued)

Operator Action	Message Window and Ventilator Response	Explanation
	[57 COMPLIANCE]	Start of compliance and safety valve check.
	[571 COMPLIANCE]	Tests safety valve in the open state.
	[572 COMPLIANCE]	Tests and calculates compliance values at 30, 60, and 85 cmH_2O.
	[572 COMPL=XX.X] (where X is a digit from 0 to 9)	Displays compliance values calculated compliance values at 30, 60, and 85 cmH_2O.
	If calculated compliance is not within limits, this message scrolls: [THE COMPLIANCE CALCULATION IS OUT OF RANGE. A DEFAULT COMPLIANCE OF 0.1 WILL BE USED].	
If compliance is not within limits, ensure that the patient wye is blocked. Check or replace patient circuit. Repeat the test by pressing <*> twice, then <ENTER>.		If the test fails again, have the ventilator serviced before using it.
	[573 COMPLIANCE]	Tests safety valve in the closed state.
	[58 AREA RATIO]	Start of area ratio and PEEP test.
	[581 AREA RATIO]	Crosschecks PEEP/CPAP pressure sensor against differential pressure sensor.
	[582 AREA RATIO]	Verifies that PEEP/CPAP pressure sensor begins at 0 cmH_2O.
	[583 AREA RATIO]	O_2 flow set to 2 Lpm.
Adjust the PEEP/CPAP control knob to the values requested by message window.	[583 SET PEEP=35]	This message appears and beep tones sound to prompt the operator to turn the knob until 35 appears in the cmH_2O window. As the displayed value comes close to the desired setting, a long series of beep tones sounds and [PLEASE PAUSE] appears in the message window. When the desired setting is nearly reached, the display locks in that value and will not allow further adjustment until the next prompt.
	[583 SET PEEP=30]	Turn knob until cmH_2O window shows 30 cmH_2O (± 5%).
	[583 SET PEEP=20]	Turn knob until cmH_2O window shows 20 cmH_2O (± 5%).
	[583 SET PEEP=15]	Turn knob until cmH_2O window shows 15 cmH_2O (± 5%).
	[583 SET PEEP=10]	Turn knob until cmH_2O window shows 10 cmH_2O (± 5%).
	[583 SET PEEP=5]	Turn knob until cmH_2O window shows 5 cmH_2O (± 5%).

Table 5-3. TEST Procedure (continued)

Operator Action	Message Window and Ventilator Response	Explanation
	[583 SET PEEP = 0]	Turn knob until cmH_2O window shows 0 cmH_2O (± 5%).
	[A/R AVG = X.XX] (where X is a digit from 0 to 9).	Displays average area ratio value.
	[59 NEBULIZER]	Start of nebulizer test.
	[591 NEB ATTACHED/]	Asks if nebulizer is attached. If a key is not pressed within 15 seconds, the [TIMED OUT] message appears. The test fails if <ENTER> is pressed when no nebulizer is attached. Repeat the test by pressing <*> twice, then <ENTER>.
Press <ENTER> to test nebulizer. (Press <CLEAR> if nebulizer is not attached.)	[592 TESTING.....]	Tests nebulizer with O_2. The O_2 flow is displayed in the TIDAL VOL liters window. The exhalation sensor flow value is displayed in the O_2% window.
	[593 TESTING.....]	Tests nebulizer with air. The air flow is displayed in the PEAK FLOW lpm window. The exhalation sensor flow value is displayed in the O_2% window.
	[60 COMPRESSOR]	Start of compressor test.
	[601 DISCONNECT AIR]	Prompts operator to disconnect air supply. If air is not disconnected and <ENTER> is not pressed within 30 seconds, the [TIMED OUT] message appears. Repeat the test by pressing <*> twice, then <ENTER>.
Disconnect the ventilator from the wall air supply and press <ENTER>.	[601 COMPR ATTACH/] (This prompt may not be displayed if the compressor is attached and running normally.)	Asks operator if the compressor is attached. If <ENTER> is not pressed within 15 seconds, the [TIMED OUT] message appears. Repeat the test by pressing <*> twice, then <ENTER>.
Press <ENTER> to test the compressor. (Press <CLEAR> if a compressor is not attached.)	[602 TESTING.....]	Measures flow at 120 Lpm if compressor is on. Test fails if <ENTER> is pressed when no compressor is attached.

Table 5-3. TEST Procedure (continued)

Operator Action	Message Window and Ventilator Response	Explanation
	[61 TEST BUV]	Start of Back Up Ventilator (BUV) test.
	[611 TEST BUV]	Monitors BUV breath rate. Verifies that the air and O_2 crossover system works. The operator is required to connect and disconnect the O_2 and air supplies.
	[611 CONNECT AIR] (This prompt appears only if the compressor is not present.)	Prompts operator to connect air supply. The [TIMED OUT] message appears if air is not connected and <ENTER> pressed within 30 seconds. Repeat the test by pressing <*> twice, then <ENTER>.
Connect the ventilator to the wall air supply if the compressor was not available. Press <ENTER>.	[612 DISCONNECT 02]	Prompts operator to disconnect the oxygen supply.
Disconnect the ventilator from the wall oxygen supply. Press <ENTER>.	[612 TESTING.....]	Ventilator verifies gas supply switch-over circuit action.
Unblock the wye by removing the #2 stopper from the patient wye. Press <ENTER>.	[613 UNBLOCK WYE]	Prompts operator to unblock the patient service circuit.
		Calculates tidal volume when BUV air volume is supplied by air. The ventilator displays BUV air volume in ml in the PEAK FLOW lpm window.
Connect the ventilator to the wall oxygen supply.	[614 CONNECT 02]	Prompts operator to reconnect oxygen.
	[614 TESTING.....]	Calculates tidal volume when BUV O_2 volume is supplied by oxygen. The ventilator displays BUV O_2 volume in ml in the TIDAL VOL liters window.
See Figure 5-3 for an illustration of keys pressed during this test.	[62 FRONT PANEL]	Start of keyboard test (verifies each key row and column works). For the following steps: If you press the wrong key, [INVALID KEY] appears and you can try once more. If you do not press the correct key within 15 seconds, the following message scrolls: [THIS TEST HAS FAILED TO MEET THE STANDARDS SET FOR THIS SECTION OF EST. YOU MAY RERUN THIS TEST BY PRESSING THE * KEY...]. Press <*> twice, then <ENTER> to repeat the test.
	[621 PUSH ALRM RESET]	
Press the <ALARM RESET> key.	[622 PUSH MANUL INSP]	
Press the <MANUAL INSPIRATION> key.	[623 PUSH MANUL SIGH]	
Press the <MANUAL SIGH> key.	[624 PUSH CLEAR]	
Press the <CLEAR> key.		

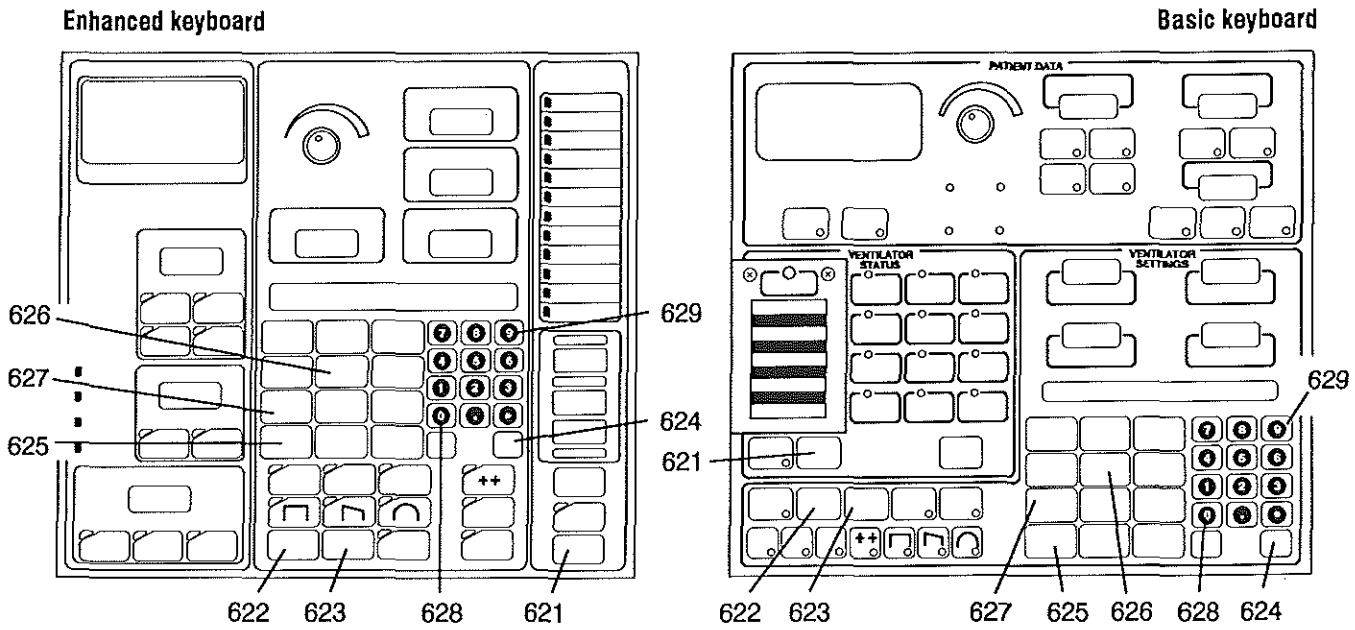


Figure 5-3. Location and Order of Requested Keys During Series 62 Test Steps

Table 5-3. TEST Procedure (continued)

Operator Action	Message Window and Ventilator Response	Explanation
Press the <LOW EXHALED TIDAL VOLUME> key.	[625 PUSH LO EXH TV]	
Press the <O_2%> key.	[626 PUSH O2%]	
Press the <HIGH PRESSURE LIMIT> key.	[627 PUSH HI PR LMT]	
Press the <0> key.	[628 PUSH 0]	
Press the <9> key.	[629 PUSH 9]	

Table 5-3. TEST Procedure (continued)

Operator Action	Message Window and Ventilator Response	Explanation
	[63 TEST DCI]	Start of Digital Communications Interface (DCI) test. This test is run whether or not the DCI option is installed; starts automatically after keyboard test is completed.
	[631 TEST DCI]	Tests channel A (intelligent communications port).
	[632 TEST DCI]	Tests channel B (printer communications port).
	[633 TEST DCI]	Tests the real-time clock.
	[634 TEST DCI]	Tests channel C (7202 Display).
	[635 TEST DCI]	Tests channel D (not assigned).
		NOTE – [DCI INOPERATIVE] appears if a DCI test fails or the option is not installed. Test failure does not affect normal ventilator operation.
	[EST PASS]	No errors were detected. Normal ventilator operation begins automatically. Do not turn off the ventilator until ventilation begins, otherwise an error message appears the next time the ventilator is turned on.
	OR	
	[EST COMPLETE– EST HAS FINISHED AND HAS DETECTED A NONCRITICAL ERROR. PERFORMANCE MAY BE AFFECTED OR NONCRITICAL SUBSYSTEMS MAY NOT WORK. ASSESS RISK/BENEFIT BEFORE USING THIS UNIT].	A noncritical error was detected.
Press <ENTER> to stop the scrolling message.	[EST COMPLETE]	The [EST COMPLETE] message disappears after a few seconds.
	[OVERRIDE–ENTER]	Prompts operator to press <ENTER> to override EST. Pressing any other key repeats EST.
		Overriding bypasses EST. This abnormal conclusion state, EST Bypassed, is logged into battery-backed memory. [EST BYPASSED] is displayed when viewing the last EST results until EST is rerun again and passed.
WARNING – *Make certain that overriding [EST COMPLETE] does not place a patient at risk before using the ventilator.*		
Press <ENTER> to override EST and begin conditional ventilation.	Ventilation begins.	Ventilation is conditional.
	OR	

Table 5-3. TEST Procedure (continued)

Operator Action	Message Window and Ventilator Response	Explanation
	[EST FAIL—EST HAS FINISHED AND HAS DETECTED A CRITICAL ERROR. WE RECOMMEND THAT THIS UNIT NOT BE USED UNTIL SERVICED. OVERRIDE MAY PLACE PATIENT AT RISK].	A critical error has been detected.
Press <ENTER> to stop the scrolling message.	[EST FAIL]	The [EST FAIL] message disappears after a few seconds.
	[OVERRIDE—ENTER]	Prompts operator to press <ENTER> to override EST. Pressing any other key repeats EST.
WARNING – *Do not use a ventilator that fails EST without first verifying its operational readiness. Use methods independent of EST. then determine that a patient will not be placed at risk.*		
Press <ENTER> to override EST and begin ventilation.	Ventilation begins.	Ventilation is conditional.

EST Conclusion States

WARNING – *Do not use or override a ventilator that fails EST without verifying its operational readiness. Your department must develop a protocol to define when, and under what conditions, a ventilator can begin conditional operation after an [EST COMPLETE] or an [EST FAIL] state. Always assess the possible risk to a patient before overriding an [EST COMPLETE] or an [EST FAIL] state. Then determine that a patient is not placed at risk by using the ventilator.*

A ventilator which completes EST without detecting any errors displays the message [EST PASS] and the ventilator automatically begins normal operation. If one or more errors are detected, the message window indicates either [EST COMPLETE] or [EST FAIL] depending on the type of error. Do not turn off the ventilator until ventilation begins, otherwise an error message appears the next time the ventilator is turned on.

[EST COMPLETE—EST IS FINISHED AND HAS DETECTED A NONCRITICAL ERROR. PERFORMANCE MAY BE AFFECTED OR NONCRITICAL SUBSYSTEMS MAY NOT WORK...ASSESS RISK/ BENEFIT BEFORE USING THIS UNIT.]

[OVERRIDE – ENTER] is then displayed. Press <ENTER> to override EST and begin conditional ventilation. Press any key except <ENTER> to repeat EST. Ventilation begins automatically if EST is passed the second time.

NOTE – Conditional ventilation means that the ventilator has failed one or more tests – critical or noncritical – during QUEST or TEST. Override the ventilator only in accordance with an established medical department protocol for using a ventilator after EST has been overridden.

If a test defined as a critical test failed, the following message scrolls through the message window:

[EST FAIL – EST HAS FINISHED AND HAS DETECTED A CRITICAL ERROR. WE RECOMMEND THAT THIS UNIT NOT BE USED UNTIL SERVICED. OVERRIDE MAY PLACE PATIENT AT RISK...]

[OVERRIDE – ENTER] is then displayed. Press <ENTER> to override EST and begin conditional ventilation. Press any key except <ENTER> to repeat EST. Ventilation begins automatically if EST is passed the second time.

Canceling Error Messages

When you see the [EST COMPLETE] and [EST FAIL] messages and test step error messages, you can press any key to see [OVERRIDE – ENTER]. (The error messages will also time out to the override message.)

Check for the following conditions if [EST FAIL], [INVALID KEY], [TIMED OUT], or [WXYZ ERR] appear in the message window:

- The patient wye is properly blocked; a patient is not connected to the ventilator.
- The patient service circuit is properly attached and all connections are tight.
- All humidifier circuit connections (including those to and from the main flow bacteria filter) are tight.
- All nebulizer circuit connections are tight if a nebulizer is used.
- The gas supply pressures are within stated pressure limits and O_2 is connected. The air supply is connected if no compressor is attached.
- Water trap connections are tight.
- The correct keys are pressed in response to prompts.
- The prompted actions are completed within the allotted time.

Check for the conditions listed above and correct them before running EST again. To rerun QUEST, press <ALARM SILENCE> and then <ENTER>. To rerun TEST, press <ALARM SILENCE>, <++>, and then <ENTER>.

EST Error Messages and Error Codes

EST error messages describe test failures. Each message scrolls (moves through the message window from right to left) three times or until you press <ENTER>. A test has failed whenever [WXYZ ERR] is displayed.

NOTE - Good clinical practice recommends repeating a failed test. Press <*> twice then <ENTER>, to rerun a test. Have the ventilator serviced if it fails the same test on two consecutive attempts.

EST error codes use the form WXYZ. W and X represent the test series. Y represents the test step. Z qualifies the error (see Table 5-4). The date and time stamp appear next to the error code as MMDD HHNN. M, D, H, and N represent the month, day, hour, and minute when the error occurred. Note error codes when they appear. Error codes are stored in battery-backed memory with their date and time stamp; service personnel use the codes to identify ventilator problems.

Table 5-4. EST Error Code Qualifiers (What Z means in a WXYZ error code during EST)

Z Code Number	Meaning
1	Indeterminate code; use the test sequence and step numbers to isolate the fault.
2	Invalid key pressed.
3	Operator did not respond within allotted time.
4	PEEP/CPAP pressure transducer failed.
5	Absolute pressure transducer failed.
6	Differential pressure transducer failed.
7	Oxygen sensor failed.
8	Air sensor failed.
9	Exhalation sensor failed.
A	Oxygen proportional solenoid valve failed.
B	Air proportional solenoid valve failed.

NOTE – The Z codes listed above only apply to EST error codes.

Error Code Block Numbers

The ventilator can detect errors that happen during POST, QUEST, TEST, and ventilation. Blocks of error codes are reserved for specific ventilator tests and checks. Ventilator action after an error is detected is determined by the block code of the detected error. Table 5-5 lists error code blocks, the test or type of check associated with the block, and the ventilator's response to errors within each block of error codes.

Table 5-5. Error Code Blocks

Error code block numbers	Test or type of check performed	Ventilator response to detected errors
0000-29FF	POST	Back Up Ventilator mode is initiated. For PSOL errors, safety valve open is initiated.
3000-50FF and 7000-89FF	Ongoing checks that monitor system errors and communications tests	**For critical errors:** POST automatically begins. If POST fails, Back Up Ventilator is initiated. If three system errors are detected within 24 hours, these messages are displayed when the third error is detected: [1501 ERR] and then [RUN EST–DO NOT USE]. Back Up Ventilator is initiated and an audible alarm sounds. **For noncritical errors:** Noncritical errors do not cause the ventilator to restart. DCI condition codes are stored in battery-backed memory.
5000-6999	QUEST and TEST	EST scrolling messages are displayed. Error codes diagnose any detected errors. ALARM indicator lights if a critical error is detected. CAUTION indicator lights if a noncritical error is detected. The [EST FAIL] message and prompt are displayed at the end of EST if a noncritical error is detected. The operator can choose to override EST.
9000-99FF	Part of ongoing checks that monitors system faults	Detection of a system fault opens safety valve, lights VENTILATOR INOPERATIVE indicator, and sounds an audible alarm. Patient breathes room air unassisted by ventilator.

NOTE – System faults and errors use the form 99XY where XY is hexadecimal code; X is a digit (0-9) and Y is a letter (A-F).

EST Override Feature and Patient Safety

WARNING – *Puritan-Bennett urges medical departments to establish a protocol defining the conditions under which [EST COMPLETE] and [EST FAIL] states can be overridden without compromising patient safety. Operators should only override EST in accordance with this established protocol.*

The override feature in EST allows an operator to consciously override EST COMPLETE and EST FAIL states and begin conditional ventilation. Overriding a noncritical test failure (EST COMPLETE), means using the ventilator when a malfunction has been detected that may

not compromise gas delivery to a patient. Overriding a critical test failure (EST FAIL) means using the ventilator when a malfunction has been detected that may compromise gas delivery to a patient.

Puritan-Bennett recognizes that instances may arise in which ventilation is of paramount importance even though QUEST or TEST was not passed. The override feature permits conditional ventilator operation in such instances. Departmental protocols must define when, and under what circumstances, an override is acceptable. Four situations for which override might be acceptable are the following:

1. Recovery from an operator error made during EST. Repeat and pass EST or any failed EST test steps before using the ventilator. For example, if you do not respond to the prompt [SET PEEP = 35] within the allotted time, microprocessor electronics causes a time out, the test step fails, and EST ends in an EST COMPLETE state. The ventilator could be overridden and conditional ventilation begun.
2. A clinical situation, as determined by an established departmental protocol, dictates that using an impaired ventilator is the best alternative for achieving or maintaining patient safety. For example, if the disposable patient service circuits used by a medical department consistently lose more than 15 cmH_2O during [542 LEAK TEST], an established medical department protocol might approve the use of patient service circuits that retain 60 cmH_2O during this test. An operator could override the EST COMPLETE state at the end of EST and begin conditional ventilation.
3. An emergency situation covered by an established departmental protocol defines the conditions under which EST can be overridden. For example, an established medical department protocol may state that emergency use of the ventilator is better than using a resuscitator. In such circumstances EST COMPLETE and EST FAIL might be overridden to provide conditional ventilation until a fully functioning ventilator is available.
4. Override EST when an operator has inadvertently invoked TEST when QUEST was desired instead.

WARNING – *The examples given above do not constitute a recommendation of a protocol by Puritan-Bennett. Puritan-Bennett recommends not using the ventilator when a pressure of 90 cmH_2O cannot be achieved in a patient service system.*

EST Test Sequences

Table 5-6 lists EST sequence test names, the subsystem tested, the test steps, and the EST version that performs the step.

An asterisk (*) before a test step indicates that a detected error is defined as noncritical if the error code ends in 1 (that is, Z is 1 in the error code WXYZ). For example, error code 5561 means an error in a noncritical flow sensor test.

Table 5-6. EST Test Sequences

Test Name	Subsystem Tested	Test Step	EST Version Quick	EST Version Total
Battery-backed memory	Battery-backed memory	511 – test battery-backed memory	X	X
		512 – checksum battery-backed memory	X	X
Autozero pressure transducers	PEEP/CPAP, absolute pressure, and differential pressure sensors	521 – verify wye blocked	X	X
		521 – autozero PEEP/CPAP pressure sensor	X	X
		522 – calibrate absolute pressure sensor	X	X
		523 – autozero differential pressure sensor	X	X
		524 – verify O_2 connection	X	X
		525 – verify air connection	X	X
***WARNING** – A failure in steps 531-535 could indicate a patient is connected to the ventilator.*				
Check for patient connected	Verifies patient disconnected from ventilator	531 – check PEEP = 0	X	X
		532 – establish 10 Lpm air flow; compare with value measured by exhalation flow sensor	X	X
		533 – calculate patient compliance; pressurize to 30 cmH_2O; record time required; display differential pressure value	X	X
		534 – monitor differential pressure sensor	X	X
		535 – compare differential pressure sensor vs absolute pressure sensor at 30 cmH_2O	X	X
Leak test	Patient service system	*541 – air flow set to 10 Lpm	X	X
		*541 – pressurize patient tubing to 90 cmH_2O	X	X
		*543 – compare differential pressure sensor vs absolute pressure sensor at 90 cmH_2O	X	X
		*542 – monitor differential pressure sensor	X	X
Air flow sensor vs exhalation flow sensor	Air flow and exhalation flow sensors	550 – flush system with air	–	X
		551 – test air flow sensor vs exhalation flow sensor at 0 Lpm	–	X
		552 – test air flow sensor vs exhalation flow sensor at 20 Lpm	–	X
		553 – test air flow sensor vs exhalation flow sensor at 50 Lpm	–	X

Table 5-6. EST Test Sequences (continued)

Test Name	Subsystem Tested	Test Step	EST Version Quick	EST Version Total
Air flow sensor vs exhalation flow sensor (continued)		554 – test air flow sensor vs exhalation flow sensor at 100 Lpm	--	X
		555 – test air flow sensor vs exhalation flow sensor at 120 Lpm	--	X
		*556 – test air flow sensor vs exhalation flow sensor at 180 Lpm, only if wall air attached; otherwise test compressor at 120 Lpm	--	X
		558 – establish 10 Lpm flow through air sensor (for Flow-by offsets)	--	X
		559 – establish 20 Lpm flow through air sensor (for Flow-by offsets)	--	X
		557 – autozero O_2 and air proportional solenoid valves (PSOLs) at 1.0 Lpm	X	X
O_2 flow sensor vs exhalation flow sensor	O_2 and exhalation flow sensors	560 – flush system with O_2	--	X
		561 – test O_2 flow sensor vs exhalation flow sensor at 0 Lpm	--	X
		562 – test O_2 flow sensor vs exhalation flow sensor at 20 Lpm	--	X
		563 – test O_2 flow sensor vs exhalation flow sensor at 50 Lpm	--	X
		564 – test O_2 flow sensor vs exhalation flow sensor at 100 Lpm	--	X
		565 – test O_2 flow sensor vs exhalation flow sensor at 120 Lpm	--	X
		*566 – test O_2 flow sensor vs exhalation flow sensor at 180 Lpm	--	X
		567 – establish 0 Lpm flow through O_2 and air sensors (for Flow-by offsets)	--	X
		568 – establish 10 Lpm flow through O_2 sensor (for Flow-by offsets)	--	X
		569 – establish 20 Lpm flow through O_2 sensor (for Flow-by offsets)	--	X
Safety valve and compliance calculation	Safety valve and patient service system	571 – open safety valve; attain maximum O_2 flow	--	X
		571 – monitor differential pressure sensor (differential pressure <20 cmH_2O)	--	X
		*572 – O_2 set to 5 Lpm	X	X

Table 5-6. EST Test Sequences (continued)

Test Name	Subsystem Tested	Test Step	EST Version Quick	EST Version Total
Safety valve and compliance calculation (continued)		*572– calculate compliance at 30 cmH_2O; sample O_2 flow sensor, differential pressure sensor	X	X
		*572– calculate compliance at 60 cmH_2O; sample O_2 flow sensor, differential pressure sensor	X	X
		*572– calculate compliance at 85 cmH_2O; sample O_2 flow sensor, differential pressure sensor	X	X
		573– close safety valve; O_2 set to 2 Lpm at 85 cmH_2O	--	X
		573– monitor absolute pressure sensor until stable; test absolute pressure sensor at cracking pressure limits (90-150 cmH_2O) with low flow	--	X
		573– O_2 set to maximum flow; monitor absolute pressure sensor; test at cracking pressure limits (80-160 cmH_2O) with high flow	--	X
Check PEEP and calculate area ratio	Differential and PEEP transducers	581– check PEEP/CPAP pressure sensor vs differential pressure sensor at 0 cmH_2O	X	X
		582– verify PEEP/CPAP pressure sensor begins at 0 cmH_2O	X	X
		*583– O_2 set to 2 Lpm	X	X
		*583– adjust PEEP to 35, 30, 20, 15, 10, 5, and 0 cmH_2O	X	X
		*583– put area ratio array into battery-backed memory; update average area ratio	X	X
Nebulizer (if attached)	Nebulizer	591– verify nebulizer attached	--	X
		592– test nebulizer with O_2 flow	--	X
		593– test nebulizer with air flow	--	X
Compressor (if attached)	Compressor	601– verify compressor on	--	X
		602– test with flow = 120 Lpm	--	X

Table 5-6. EST Test Sequences (continued)

Test Name	Subsystem Tested	Test Step	EST Version Quick	EST Version Total
BUV	Back up ventilator	611 – monitor BUV breath rate	--	X
		612 – test crossover solenoid with air vs O_2	--	X
		613 – calculate BUV air volume; sample differential pressure sensor, O_2 flow sensor	--	X
		614 – calculate BUV O_2 volume; sample differential pressure sensor, O_2 flow sensor	--	X
Front panel interface	*Keyboard display panel*	621 – test <ALARM RESET>	--	X
		622 – test <MANUAL INSPIRATION>	--	X
		623 – test <MANUAL SIGH>	--	X
		624 – test <CLEAR>	--	X
		625 – test <LOW EXHALED TIDAL VOLUME>	--	X
		626 – test <O_2%>	--	X
		627 – test <HIGH PRESSURE LIMIT>	--	X
		628 – test <0>	--	X
		629 – test <9>	--	X
DCI	Digital communications *interface and real-time clock*	*631 – test channel A (intelligent port) with test pattern	--	X
		*632 – test channel B (printer port) with test pattern	--	X
		*633 – test real-time clock	--	X
		*634 – test channel C (7202 Display) with test pattern	--	X
		*633 – test channel D (not assigned) with test pattern	--	X

Installation and Assembly

Install assemblies and accessories on the 7200ae Ventilator in the following order:

1. Ventilator module to pedestal
2. Humidifier circuit
3. Flex arm
4. Patient service circuit
5. O_2 Monitor, 7202 Display, and printer
6. Analog signal recorder and remote nurse's call
7. Gas supplies

Ventilator Module to Pedestal

If you ordered the ventilator module with the pedestal alone (no compressor) or if you ordered the pedestal separately, you must mount the ventilator module on top of the pedestal (see Figure 6-1). If you ordered a ventilator module and, later, order a compressor pedestal, follow the instructions provided with the compressor pedestal assembly.

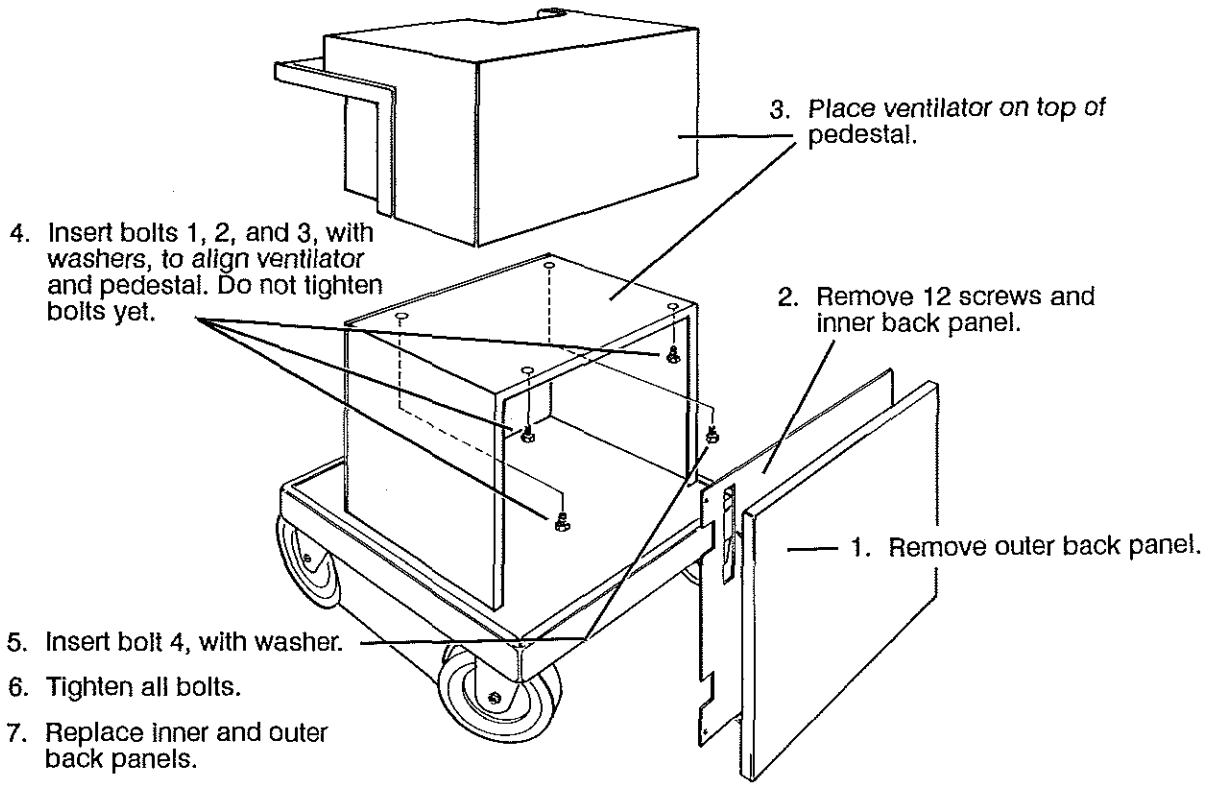
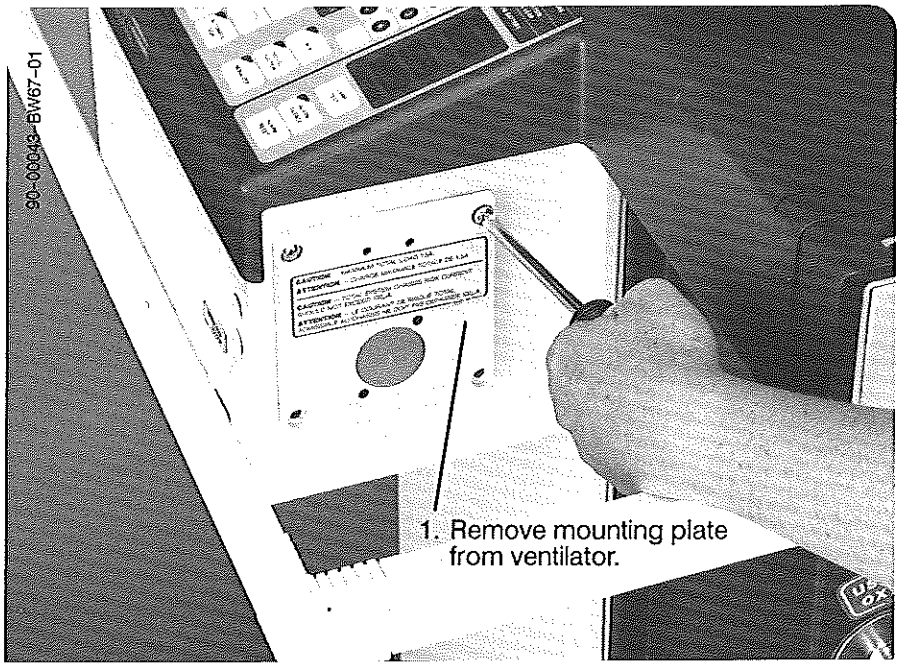


Figure 6-1. Installing the Ventilator Module to the Pedestal

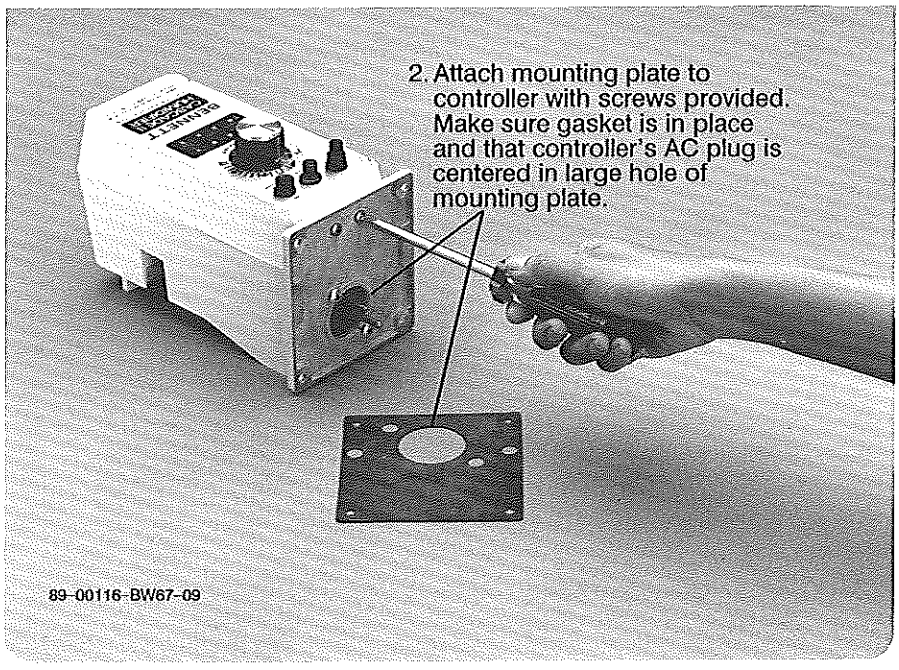
Humidifier Circuit

Figure 6-2 shows how to install the humidifier circuit, using a Cascade II Humidifier. When other humidifiers are used, refer to the appropriate operator's manual for installation procedures.

WARNING – *Use a Puritan-Bennett Temperature Alarm (P/N 4-007900-00) with any humidifier that does not include an airway temperature sensor in order to warn against overheating inspired gas. Injury to the patient may result if the inspired gas becomes too hot. See Figure 6-4 to install a temperature sensor into the patient service circuit.*

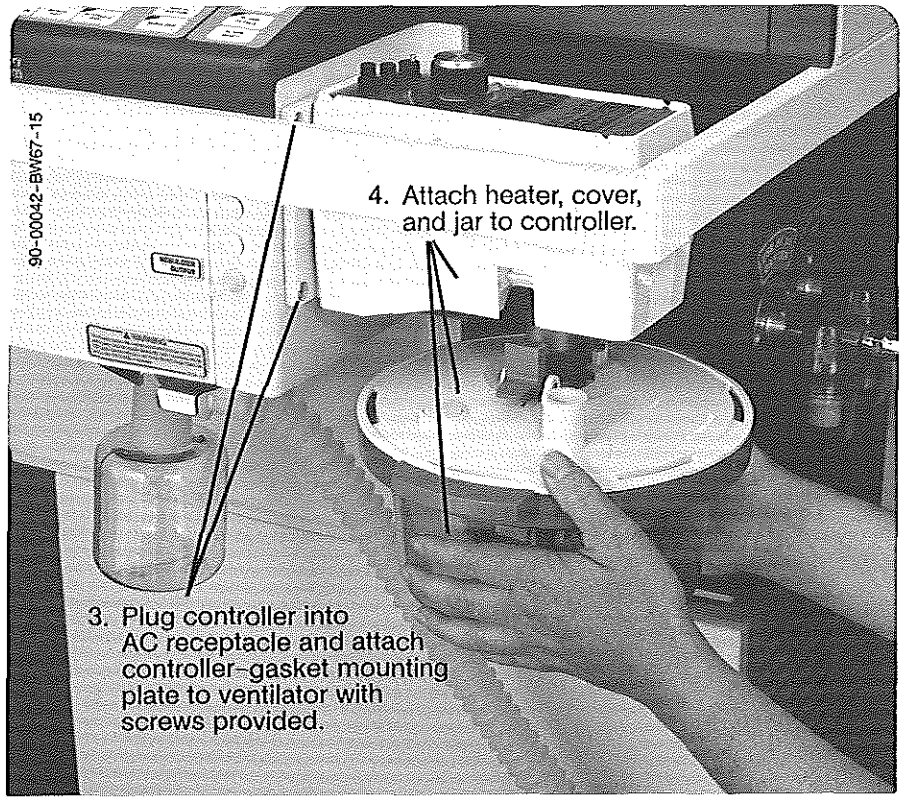


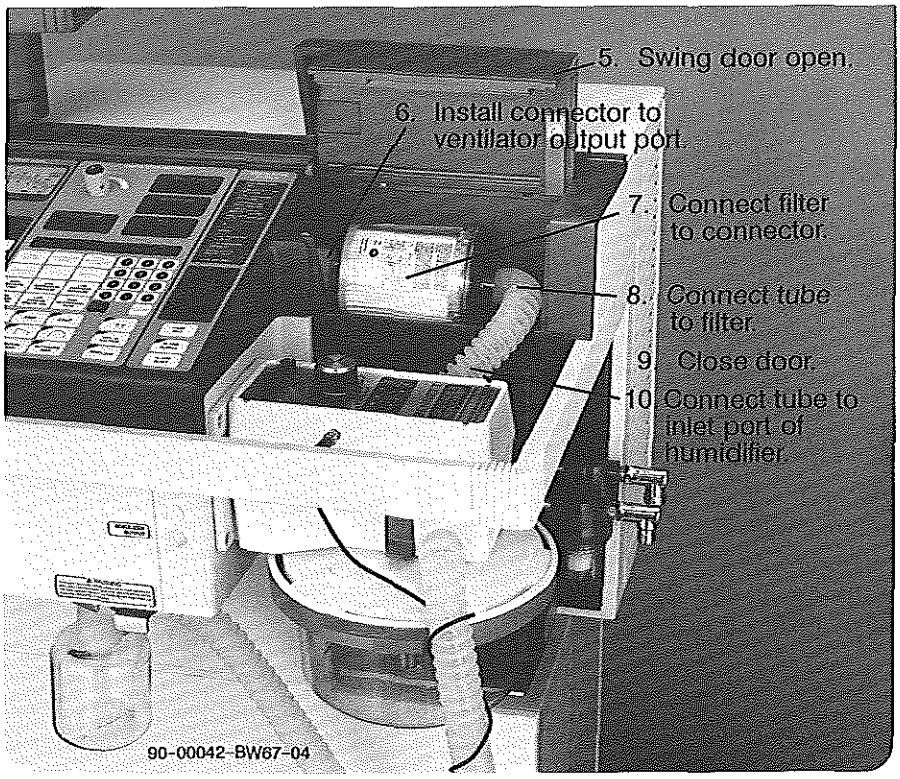
A



B

Figure 6-2. Installing the Humidifier Circuit





D

Figure 6-2. Installing the Humidifier Circuit (continued)

Flex Arm

See Figure 6-3 to install the flex arm.

The flex arm may be inserted into the threaded socket on either the right or left side of the ventilator. If you intend to use an O_2 Monitor with the ventilator, see the O_2 Monitor section in this chapter before installing the flex arm.

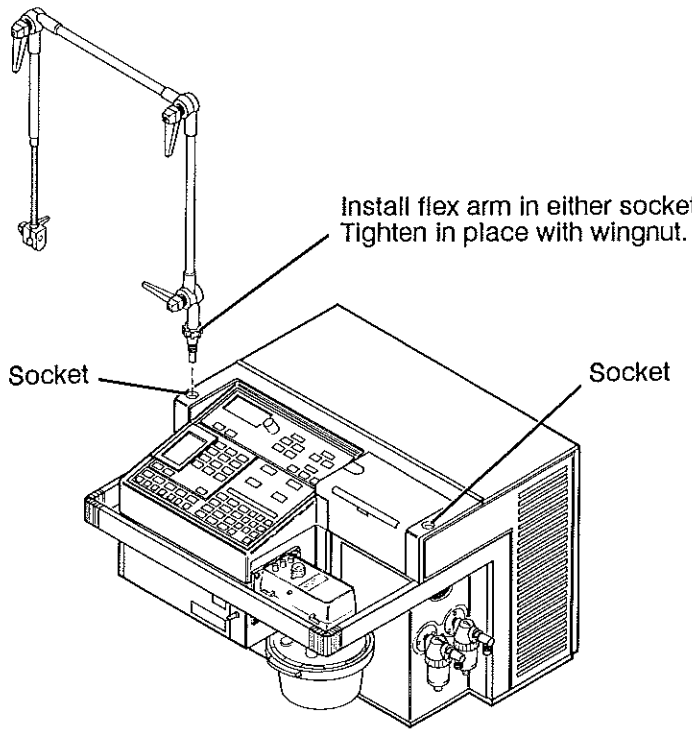


Figure 6-3. Installing the Flex Arm

Patient Service Circuit

See Figure 6-4 to install a simplified patient service circuit.

WARNING – *Only use a simplified patient service circuit on a ventilator equipped with an internal exhalation valve. Using a circuit with an external valve may cause increased expiratory resistance or occlusion, or may inhibit the ventilator's ability to sense the patient's inspiratory effort.*

WARNING – *Patient service circuits must be connected exactly as shown and described. Failure to connect the circuits properly will cause ventilator malfunction. Do not allow condensate to accumulate or tubing to become twisted or obstructed; otherwise, patient breathing efforts may increase.*

- *Drape the patient exhalation tube so that any condensate collects in the collector vial and not in the tubing.*
- *Drain in-line water traps as needed.*
- *Be sure that the patient is visually monitored by competent medical personnel. Life-threatening circumstances may arise that might not activate alarms.*

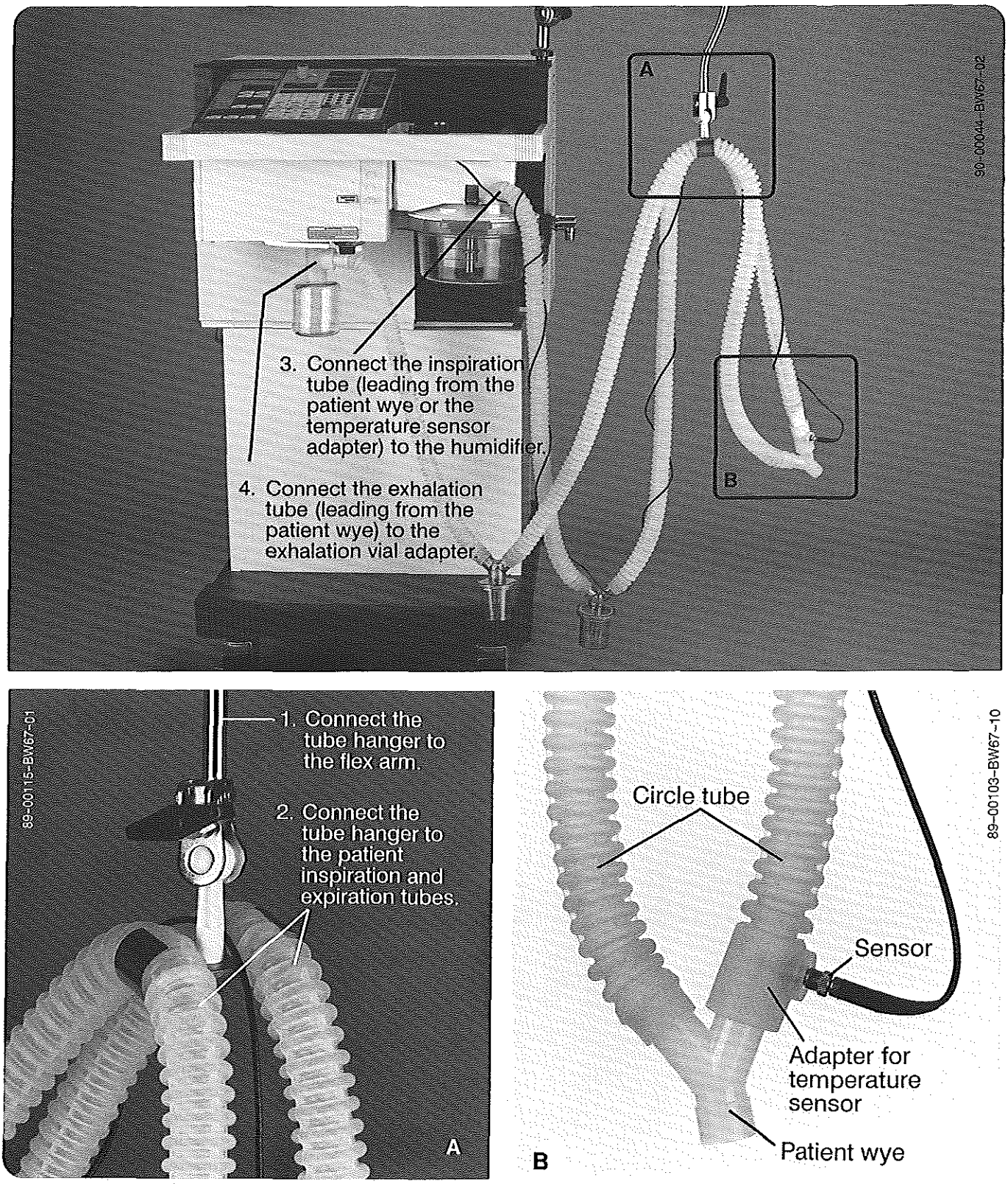


Figure 6-4. Simplified Patient Service Circuit Assembly and Installation

Install a nebulizer, if desired, in the inspiratory side of the simplified patient service circuit. Place the nebulizer between the tube hanger and the patient wye. Connect the nebulizer tube between the nebulizer and the nebulizer output port on the ventilator. See Figure 6-5.

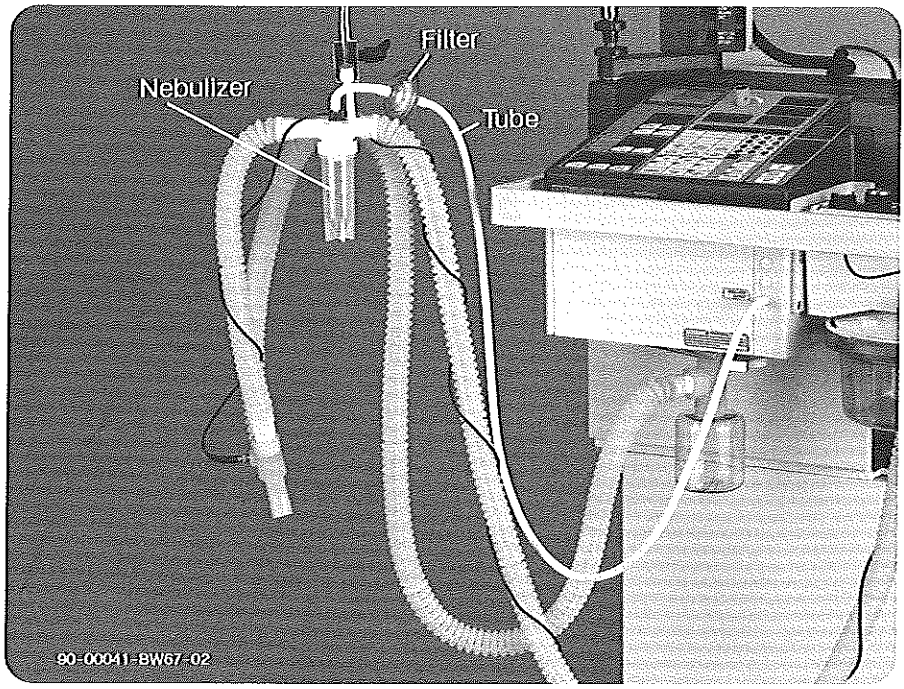


Figure 6-5. Installing a Nebulizer

O_2 Monitor

Consult the operating instructions for details on installation and assembly of the O_2 monitor in use.

Figure 6-6 shows how to install the Puritan-Bennett O_2 Monitor and flex arm on the same side of the ventilator.

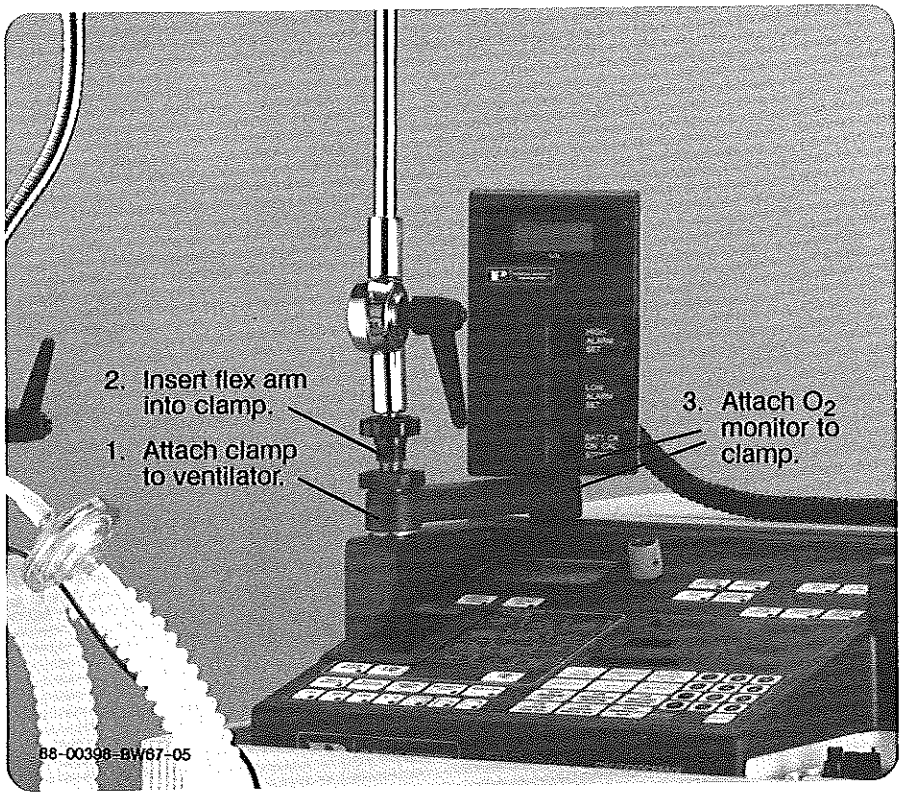


Figure 6-6. Installing the O_2 Monitor and Flex Arm on the Same Side of the Ventilator

Analog Signal Recorder and Remote Nurse's Call

To connect an analog signal recorder or a remote nurse's call to the ventilator's OUTPUT SIGNAL connector, use a plastic nine-pin connector shell. See Table 6-1 and Figure 6-7 for wiring assignments.

WARNING – *The nurse's call relay does not signal loss of power. Patients on life-support equipment should be visually monitored by competent medical personnel, since life-threatening circumstances may arise that might not activate alarms.*

Table 6-1. Pin Description of the Output Signal Connector

Pin Number	Description of Signal
1	Chassis ground
2	Pressure signal 0 to 10 VDC corresponding to −20 cmH_2O to +120 cmH_2O 0 cmH_2O equals approximately 1.4 VDC Required load is 1K impedance (minimum)
3	Pressure signal return
4	–
5	–
6	Flow signal 0 to 10 VDC corresponding to −180 Lpm to +180 Lpm 0 Lpm equals 5.0 VDC Required load is 1K impedance (minimum)
7	Flow signal return
8	Nurse's call relay Normally open; closed when activated Allowable current is 250 mA at 30 VDC (maximum)
9	Nurse's call relay return

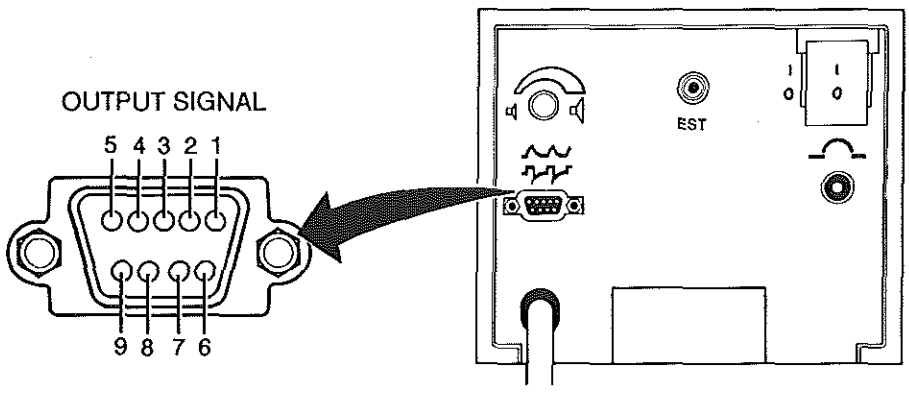


Figure 6-7. Numbering of Pins for Output Signal Connector

Gas Supplies

See Figure 6-8 to connect the gas supplies to the ventilator.

The water trap and filter assemblies for the gas supplies are installed at the factory prior to shipping the ventilator. If it becomes necessary to disassemble these for any reason, see Chapter 4.

WARNING – *Gas supply connections conform to standards set forth in the Diameter Index Safety System (DISS) for air and oxygen (3/4-16 and 9/16-18 respectively). Do not attempt to change these connections. Do not use any gases with the ventilator other than air or oxygen.*

CAUTION – The pore size of the gas supply filter is 0.3µ. The small pore size is intended for the protection of the ventilator. Do not replace these filters with a filter of larger pore size. Always use a clean, dry source. The gas supply filters are not designed to remove water vapor from wet air. Damage to the ventilator may result if the air or O_2 supply is particularly wet or dirty.

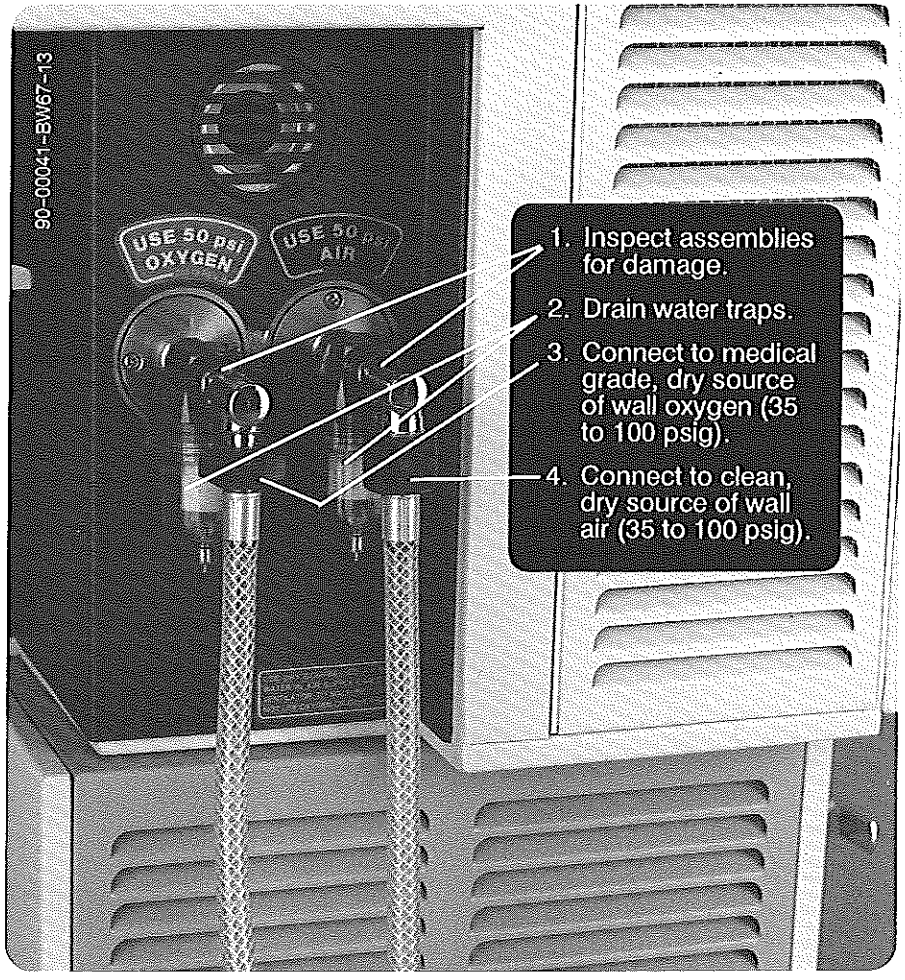


Figure 6-8. Connecting the Gas Supplies to the Ventilator

Electrical Supply

WARNING – *Replace the power cord and plug if they are damaged. Using a damaged cord may result in an electrical shock.*

WARNING – *A 115 VAC ventilator equipped with a compressor pedestal draws approximately 8.5 amperes (rms). When using a ventilator with a compressor pedestal in conjunction with other medical equipment, be sure that the total electrical load does not exceed the ampere rating of the branch circuit to which the ventilator is connected. (A branch circuit includes all outlets serviced by one circuit breaker.) If the maximum current drain through a branch circuit exceeds its rating, the branch circuit breaker will open and the ventilator will initiate a Power Disconnect alarm.*

WARNING – *The ventilator has a three-pronged grounding plug for protection against shocks. Connect the ventilator's power cord directly into a properly grounded three-wire receptacle only.*

NEVER cut or remove the grounding prong from the equipment or attempt to defeat the grounding feature.

CAUTION – Before connecting the ventilator to an AC outlet, check the information on the data plate, located on the utility panel, and verify that the AC power is of proper voltage and frequency. Serious damage to the ventilator may result if AC voltage and frequency do not match those specified on the data plate.

Checkout Procedures

Test the ventilatory system for operational readiness:

- Run lamp test (described in Chapter 4).
- Run Total Extended Self-Test (TEST) (described in Chapter 5).
- Verify that the humidifier is operating (see the humidifier operating instructions for details).
- Verify that the 7202 Display is operating. Press <ALARM RESET> twice to clear and reset the screen. Refer to the 7202 Display appendix for further details.
- Verify that the printer is connected, turned on, and has paper.
- Follow the preoperational procedures described in Chapter 3.

Glossary

Term	Definition
[AIRWAY PRESS DISCONN]	Message appearing in the message window when disconnect ventilation occurs. Invoked automatically whenever microprocessor electronics determines that patient tubing is disconnected or plugged. See also Disconnect Ventilation.
<AIRWAY PRESSURE cmH_2O>	On the Basic keyboard, the PATIENT DATA key used to display airway pressure in cmH_2O via the analog meter. See also Analog Meter.
ALARM	On the Basic keyboard, the red Alarm Summary Display indicator that flashes whenever any individual alarm indicator (except LOW BATTERY and I:E) is triggered. Stays lit as long as any individual alarm indicator is flashing. See also CAUTION and NORMAL. For the Enhanced keyboard, see VENTILATOR ALARM.
Alarm Indicator	One of the 12 VENTILATOR STATUS indicator lights that flashes when the ventilator detects the associated alarm condition. Unless silenced, the audible alarm sounds and the nurse's call is activated in conjunction with most alarm conditions. An alarm indicator glows steadily when the condition that triggered it is corrected or corrects itself. See also Auto-reset and Alarm Threshold.
<ALARM RESET>	The VENTILATOR STATUS key that resets all triggered alarm indicators, turns off the VENTILATOR ALARM and CAUTION indicators, cancels the alarm silence feature, and starts the Battery Check. See also <ALARM SILENCE>.
<ALARM SILENCE>	The VENTILATOR STATUS key that silences the audible alarm and nurse's call for two minutes after you press a key. This is cancelled by loss of AC power, running of POST, <ALARM RESET>, and <LAMP TEST>. See also <ALARM RESET>.
Alarm Summary Display	A section in the VENTILATOR STATUS section of the keyboard with six indicator lights that summarize patient and ventilator alarm status information. Has five indicators: VENTILATOR ALARM, CAUTION, BACK UP VENTILATOR, SAFETY VALVE OPEN, NORMAL and VENTILATOR INOPERATIVE. See also Alarm Threshold.

Term	Definition
Alarm Threshold	The upper or lower limit value, defined by an operator-selected setting, used to trigger an alarm. The alarm threshold keys are used to set trigger values for six breath delivery settings (HIGH PRESSURE LIMIT, HIGH RESPIRATORY RATE, LOW EXHALED MINUTE VOL, LOW EXHALED TIDAL VOL, LOW INSPIRATION PRESSURE, and LOW PEEP/CPAP PRESSURE). See also Alarm Indicator.
Analog Meter	The analog display in the PATIENT DATA section which shows airway pressure in cmH_2O. On the Basic keyboard, the analog meter may also show exhaled volume uncorrected to BTPS. See also <AIRWAY PRESSURE cmH_2O> and <EXHALED VOLUME liters>.
APNEA	The indicator that lights when the ventilator detects apnea (the respiratory condition in which a patient fails to breathe). The ventilator recognizes apnea as a gas flow less than the smaller of 50 ml through the exhalation flow sensor of 10% of the tidal volume, during an operator-selected interval. This interval is the period of time between the start of an exhalation and the start of the next exhalation. The operator specifies the interval duration (10-60 seconds) used to define apnea. See also Apnea Ventilation and Apnea Ventilation Parameters.
Apnea Ventilation (AV)	The emergency ventilatory mode that automatically starts when apnea is detected and, if operating in CMV or SIMV, the LOW INSPIRATORY PRESSURE alarm is not active. [APNEA VENTILATION] is then displayed in the message window. Operator-selected apnea parameters go into effect when apnea ventilation is invoked.
Apnea Ventilation Parameters	Operator-selected parameters (apnea interval, apnea tidal volume, apnea peak flow, apnea respiratory rate, and apnea O_2%) which go into effect when apnea ventilation is invoked.
Area Ratio	The ratio of the control surface area of the exhalation valve to the surface area of the valve defined by the seal. Area ratio is determined during EST and is used to calculate PEEP. The default value is 1.40. See also Extended Self-Test and PEEP.
Assist Breath	Also known as a Patient-initiated Mandatory breath. Occurs in the CMV and SIMV modes when patient effort reduces system pressure below the operator-selected sensitivity; illuminates the ASSIST breath-type indicator. See also SIMV and Patient-initiated Mandatory Breath.
<AUTOMATIC SIGH>	The key used to select operator-defined values for the four parameters that define a sigh breath (a special kind of mandatory breath) for the automatic sigh function. See also Sigh Breath and Manual Sigh.
Auto-reset	The ventilator feature that automatically resets the VENTILATOR ALARM display, individual alarm indicators, and the audible alarm. Auto-resetting the triggered alarm condition (if only one alarm is active) turns off the VENTILATOR ALARM display and the audible alarm. The individual alarm indicator and the CAUTION display are illuminated until reset with <ALARM RESET>.

Term	Definition
Auto-reset (continued)	Because the I:E and LOW BATTERY alarms do not cause the alarm summary display to light, the ventilator displays NORMAL when these alarms are auto-reset. See also Alarm Indicator.
BACK UP VENTILATOR (BUV)	The Alarm Summary Display indicator that lights when the Back Up Ventilator emergency ventilatory mode starts. The BUV mode automatically begins when the third system error is detected in 24 hours. BUV is an emergency alternative to "handbagging" a patient with a resuscitator. See also System Error.
Basic Keyboard	The charcoal gray keyboard with colored borders to separate the sections. The PATIENT DATA section is at the top, the VENTILATOR STATUS section is on the left, and the VENTILATOR SETTINGS section is on the lower right. Two keys for the analog meter allow the operator choose between airway pressure and exhaled volume. See <AIRWAY PRESSURE cmH2O>, <EXHALED VOLUME liters>, and Enhanced Keyboard.
Battery-Backed Memory (BBR)	A microprocessor memory section that stores current ventilator settings when the ventilator is turned off and logs system errors, system faults, and bypassed or failed EST tests. (BBR means Battery-Backed RAM, where RAM means Random Access Memory.) See also Memory.
Breath Cycle, Breath Period	See Cycle Interval.
Breath Delivery	See Delivery, of a Breath.
Breath Parameters	The ventilator settings that allow the operator to specify the characteristics of mandatory and spontaneous breaths. Six settings define mandatory breaths. They are: tidal volume, respiratory rate, peak inspiratory flow, sensitivity, O_2%, and plateau. Two settings, O_2% and sensitivity, define spontaneous breaths. See Current Setting.
Breath–Type Indicator	One of the four PATIENT DATA indicators that light up to show the type of breath in progress (ASSIST, PLATEAU, SIGH, and SPONTANEOUS). See also Assist, Plateau, Sigh, and Spontaneous.
BTPS (Body Temperature and Pressure, Saturated)	A standard set of conditions for measuring gas volume. Volume is corrected to body temperature (37° C), ambient barometric pressure, and saturated with water vapor.
BUV	See BACK UP VENTILATOR.
CAUTION	The yellow Alarm Summary Display indicator that lights when the ventilator auto-resets an alarm indicator. (This does not apply to the I:E or LOW BATTERY alarms.) See also Auto-reset.
Circuit Breaker	See Reset Button.

Term	Definition
<CLEAR>	The VENTILATOR SETTINGS key used to erase a parameter value displayed in the message window. Pressing <CLEAR> allows a new value to be entered but does not affect the current value. See also <ENTER>.
cmH_2O Window	The PATIENT DATA window that shows digital pressure values for MEAN AIRWAY PRESSURE, PEAK AIRWAY PRESSURE, PEEP/CPAP, and PLATEAU PRESSURE.
<CMV> (Continuous Mandatory Ventilation)	The VENTILATOR SETTINGS mode key used to select the ventilation mode in which all delivered breaths are ventilator-controlled or assisted, and volume and flow rate-limited. Operator-initiated breaths may also be delivered. Also the CMV ventilation mode.
Compressor	The optional device that provides an air source for the ventilator if wall air fails or is not available. The 7200 Series ventilator module sits on top of the compressor, if installed.
Conditional Ventilation	Type of ventilation invoked when EST FAIL or EST COMPLETE state is overridden. Conditional ventilation should only be used in accordance with institutional protocol because it signifies that the ventilator is not operating normally. See also Critical Error, Extended Self-Test, and Noncritical Error.
<CPAP> (Continuous Positive Airway Pressure)	The VENTILATOR SETTINGS mode key used to start the ventilation mode in which all breaths are spontaneous (except automatic sighs and operator-initiated breaths).
Critical Test	A subtest during Quick Extended Self-Test or Total Extended Self-Test whose failure could compromise patient safety. Such a failure is called a critical error. A critical test has failed if EST displays an error code which ends in a number from 4 to 9 or with an A or B. See Noncritical Test and Extended Self-Test.
Cycle Interval	The period in a mandatory breath from the beginning of inspiration to the beginning of inspiration in the following mandatory breath. The operator-selected respiratory rate setting determines the cycle interval in mandatory breathing. The cycle interval equals 60 seconds/Respiratory Rate for normal mandatory breaths. For sigh breaths, sigh cycle interval may equal up to twice the <RESPIRATORY RATE>. Also known as the breath cycle or breath period. See also <RESPIRATORY RATE>.
Default Setting	A preprogrammed value automatically used as a setting when no operator-specified value is currently active for a setting, or when BBR is lost or erased. See also Current Setting.
Delivery of a Breath	The part of the cycle interval in a mandatory breath in which gas is delivered to a patient. See Mandatory Breath.
Descending Ramp Waveform Key	Key used to select descending ramp waveform. See also Waveform key.

Term	Definition
Disconnect Ventilation (DV)	The emergency ventilatory mode that protects the patient from excessive airway pressure if the patient pressure tubing is disconnected. The ventilator automatically starts this mode, which delivers ventilator-initiated breaths in accordance with operator-selected apnea parameters, if it detects pressure and flow conditions which are consistent with disconnection, milking, or occlusion of the patient tubing. [AIRWAY PRESS DISCONN] is then displayed in the message window. See also Apnea Ventilation.
<ENTER>	The VENTILATOR SETTINGS key that causes the ventilator to accept a new setting. The last key pressed in the Entry Sequence. The new setting is accepted provided the value is within the permissible range and does not cause the I:E Ratio Check to fail. See also Entry Sequence.
Enhanced Keyboard	The predominantly multi-color keyboard, with the PATIENT DATA section on the left, the VENTILATOR SETTINGS section in the middle, and the VENTILATOR STATUS section on the right. The analog meter continously shows airway pressure. See Basic Keyboard.
Error	See Critical Error, Noncritical Error, or System Error.
Exhalation	That part of the breath cycle during which gas flows from the patient's lungs through the exhalation flow sensor. Generally defined as the interval from the end of an inspiration to the beginning of the next inspiration. See also Inspiration.
Exhalation Valve	The valve in the exhalation compartment which opens during exhalation to allow gas to flow from the lungs, and closes during inspiration to allow gas to enter the patient's lungs. See also Pneumatic System.
EXHALATION VALVE LEAK	The alarm indicator that lights if gas flowing past the exhalation valve during an expiration exceeds 10% of the delivered volume or 50 ml, whichever is greater.
<EXHALED VOLUME liters>	Only on the Basic keyboard. The PATIENT DATA key used to display volume detected by the exhalation flow sensor during inspiration and exhalation in liters on the analog meter. See also Analog Meter.
EST (Extended Self-Test)	An interactive self-diagnostic test, controlled by microprocessor electronics, that checks the ventilator's pneumatic system. POST runs whenever EST is initiated; EST can only be run if POST is passed. Prompts tell the operator what to do during the course of the EST procedure. EST has two forms—QUEST and TEST. See also POST, QUEST, and TEST.
Factory-set Parameters	See Default Setting.
Fault	See System Fault.

Term	Definition
Flow Sensor	An electrical device that converts gas flowing through it into an electrical signal. The analog electrical signal produced by the transducer is proportional to the magnitude of the measured flow of gas. See Pressure Transducer.
<HIGH PRESSURE LIMIT>	The VENTILATOR SETTINGS key used to select or review the upper limit of airway pressure which will trigger the HIGH PRESSURE LIMIT alarm indicator during a non-sigh breath. HIGH PRESSURE LIMIT is also the alarm indicator that lights when airway pressure exceeds threshold value; may also occur in disconnect ventilation. When this alarm triggers, the mandatory inspiration in progress is terminated.
<HIGH RESPIRATORY RATE>	The VENTILATOR SETTINGS key used to select or review the setting for the upper limit of delivered respiratory rate which triggers the HIGH RESPIRATORY RATE alarm indicator. HIGH RESPIRATORY RATE is also the alarm indicator triggered when the rate for the 10-breath running average is higher than the set threshold.
I:E	The alarm indicator that monitors the ratio between inspiratory time and expiratory time. It lights if the I:E ratio is greater than 1:1; i.e., inspiration is longer than expiration (e.g., 1:0.9). This alarm triggers if the duration of a mandatory breath, including the plateau value, is greater than 50% of the complete breath cycle's duration. See <I:E RATIO>.
<I:E RATIO>	The PATIENT DATA key used to display the calculated inspiratory/expiratory time ratio in the RATE/I:E window. This ratio is displayed as 1:XX.X where XX.X is: (expiration period divided by inspiratory period). See Exhalation, Inspiration, or <RESPIRATORY RATE>.
I:E Ratio Check	A microprocessor electronics-controlled check to ensure that mandatory inspiratory time is less than 75% of the cycle interval. I:E ratio is determined by the current values for tidal volume, respiratory rate, peak inspiratory flow. The I:E ratio check is automatically done after a change in waveform or in any of the following parameters: peak inspiratory flow, plateau, respiratory rate, and tidal volume.
Inspiration	The interval in a breath when gas flows into a patient's lungs. The ventilator begins inspiration on detection of a sufficient drop in airway pressure due to patient effort or after a prescribed time elapses. The operator may also initiate an inspiration using the <MANUAL INSPIRATION> key. The ventilator then delivers gas to the patient. See Mandatory Breath, <MANUAL INSPIRATION>, or Spontaneous Breath.
Inspiratory Threshold	The airway pressure at which inspiratory effort triggers a breath. This pressure equals operator-selected PEEP minus operator-selected Sensitivity. See also PEEP, Sensitivity, Assist Breath, and Spontaneous Breath.

Term	Definition
Keyboard Display Panel	The membrane touch-pad used by the operator to give instructions to the ventilator. The keyboard display panel allows the operator to specify ventilator. The keyboard display panel allows the operator to specify ventilatory settings, to review ventilator status and patient data, to activate special functions, and to perform self-test procedures.
<LAMP TEST>	The VENTILATOR STATUS key used to test all displays and lights in the keyboard display panel (including the audible alarm, nurse's call, and the analog meter). This test lasts about 40 seconds and should be done at least every time a patient is connected to the ventilator, but may be done more often, according to operator preference.
Liters Window	The PATIENT DATA window that displays the averaged values for minute, spontaneous, and tidal volumes when the corresponding PATIENT DATA keys are pressed.
LOW BATTERY	The alarm indicator that lights if an hourly check of the internal backup battery power does not detect enough power to sound the audible alarm for one hour.
<LOW EXHALED MINUTE VOL>	The VENTILATOR SETTINGS key used to select or review the alarm threshold value to trigger the LOW EXHALED MINUTE VOL alarm indicator.
<LOW EXHALED TIDAL VOL>	The VENTILATOR SETTINGS key used to select or review the alarm threshold value to trigger the LOW EXHALED TIDAL VOL alarm indicator.
<LOW INSPIRATION PRESSURE>	The VENTILATOR SETTINGS key used to select or review the alarm threshold value to trigger the LOW INSPIRATORY PRESSURE alarm indicator. LOW INSPIRATORY PRESSURE is the alarm indicator that lights when peak airway pressure fails to reach the threshold value for low inspiration pressure, for mandatory breaths only. When apnea has been detected, and the LOW INSPIRATORY PRESSURE alarm is active, the ventilator does not declare apnea ventilation. Peak inspiratory pressure must be greater than the LOW INSPIRATORY PRESSURE threshold value during the breath cycle to avoid triggering the alarm.
<LOW PEEP/CPAP PRESSURE>	The VENTILATOR SETTINGS key used to select or review the alarm threshold setting for the minimum positive pressure to be maintained throughout the cycle interval. LOW PEEP/CPAP PRESSURE also refers to the alarm indicator that triggers when PEEP/CPAP falls below the threshold setting or when more than 5 liters of gas is delivered during a spontaneous inspiration (the alarm setting must be set above "0" to be enabled).
LOW PRESSURE AIR INLET	The alarm indicator that lights if inlet pressure for the air supply is less than 35 psig and no compressor is connected, or compressor pressure is less than 7.5 psig.

Term	Definition
LOW PRESSURE O_2 INLET	The alarm indicator that lights if inlet pressure for the oxygen supply is less than 35 psig and O_2% is set to 22% or more.
Machine-initiated Mandatory Breath (MIM)	See Ventilator-initiated Mandatory Breath (VIM).
Mandatory Breath	One of the two breath types the ventilator delivers. It can be ventilator, operator, or patient-initiated. The operator specifies waveform, tidal volume, peak inspiratory flow, O_2%, and (if required) plateau. See Spontaneous Breath and Sigh.
<MANUAL INSPIRATION>	The VENTILATOR SETTINGS key that allows delivery of one operator-initiated mandatory breath. A manual inspiration resets the cycle interval.
<MANUAL SIGH>	The VENTILATOR SETTINGS key that allows delivery of one operator-initiated sigh tidal volume. No sigh is delivered if settings for automatic sigh parameters have not been selected. A manual sigh resets the cycle interval but does not change automatic sigh sequencing.
<MEAN AIRWAY PRESSURE>	The PATIENT DATA key used to display calculated mean airway pressure, averaged over one complete breath cycle, in the cmH_2O window .
Memory	The part of microprocessor electronics that stores information and instructions. The ventilator has three kinds of memory. Dynamic RAM (Random Access Memory) stores calculations while the ventilator is running. Battery-backed RAM (BBR) stores operator-selected settings when the ventilator is turned off. PROM (Programmable Read Only Memory) microchips permanently store software instructions. See also Battery-Backed Memory or Microprocessor Electronics.
Message	Words and numbers displayed in the ventilator's message window that give warnings, information, or instructions to the operator. See also Message Window and Prompt.
Message Window	The 20-character window in the VENTILATOR SETTINGS section (directly above the parameter keys) that displays current and proposed ventilator settings, messages containing warnings or instructions (prompts), and I:E ratio and EST information. See also Message and Prompt.
Microprocessor	The part of the ventilator that executes the settings entered by the operator. The microprocessor controls and processes the flow of information between microprocessor electronics, the pneumatic system, and the keyboard display panel. See Microprocessor Electronics.
Microprocessor Electronics	The printed circuit boards in the ventilator that control the pneumatic system, monitor patient and ventilator performance, and perform all calculations.

Term	Definition
<MINUTE VOLUME>	The PATIENT DATA key used to display the calculated minute volume in the liters window.
Mode	A ventilation mode. The set of rules that govern what breath types the ventilator may deliver and when they may be delivered. See CMV, SIMV, AND CPAP.
<NEBULIZER>	The VENTILATOR SETTINGS key that activates nebulization. The nebulization circuit is automatically turned off after 30 minutes and inactive if actual flow falls below 10 Lpm. Nebulization only occurs during the inspiratory phase of the breath cycle and is suspended during apnea ventilation, disconnect ventilation, or when a LOW PRESSURE AIR or O_2 INLET alarm occurs.
NORMAL	The green (or blue) Alarm Summary Display indicator that lights when a patient is being ventilated according to operator directions and no alarm, caution, or emergency condition exists. See also VENTILATOR ALARM and CAUTION.
Noncritical Test	A QUEST or TEST subtest which, if failed, does not jeopardize patient safety. Failure of a noncritical test is called a noncritical error. See also EST.
<100% O_2 SUCTION>	The VENTILATOR SETTINGS key that turns on or off oxygenation for a patient before or after tracheal suctioning. The ventilator delivers 100% oxygen for two minutes when this function starts.
<O_2%>	The VENTILATOR SETTINGS key used to select or review a value for the parameter that defines the oxygen percentage (21 - 100) in delivered gas. O_2% is also the VENTILATOR SETTINGS window that continuously displays the digital value selected for the current, operator-selected setting for the oxygen percentage of the inspiratory gas.
Operator-initiated Mandatory Breath (OIM)	A mandatory breath delivered when the operator presses the <MANUAL INSPIRATION> or <MANUAL SIGH> keys (provided no mandatory inspiration is in progress). See also <MANUAL INSPIRATION> or <MANUAL SIGH>.
PATIENT DATA Section	The section of the keyboard display panel which provides information on breath types, pressures, volumes, rates, and ratios. This section has a green background on the Enhanced keyboard or is bordered in green on the Basic keyboard.
Patient-initiated Mandatory Breath (PIM)	A mandatory breath delivered whenever the patient reduces airway pressure to the inspiratory threshold (PEEP minus sensitivity). See also PEEP, Sensitivity, Operator-initiated Mandatory Breath, or Ventilator-initiated Mandatory Breath.
Patient-initiated Mandatory (PIM) Phase	The part of the SIMV cycle during which patient inspiratory effort causes the delivery of a mandatory breath.

Term	Definition
Patient Service Circuit	The patient service circuit transports gas from the humidifier to the patient and back to the ventilator's exhalation compartment.
Patient Service System	The ventilator components that transport gas from the ventilator to the patient and back to the ventilator. This includes: the humidifier circuit (warms and humidifies gas); the exhalation flow circuit (measures exhaled gas volume); and the patient service circuit (transports gas from the humidifier circuit to the patient and back to the exhalation flow circuit). Bacteria filters are integrated in the patient service system. A nebulizer may also be included.
<PEAK AIRWAY PRESSURE>	The PATIENT DATA key used to display maximum pressure reached during a mandatory inspiration. This measurement appears in the cmH_2O window.
PEAK FLOW lpm	The VENTILATOR SETTINGS window used to continuously display the digital value of the current, operator-selected setting for peak inspiratory flow.
<PEAK INSPIRATORY FLOW>	The VENTILATOR SETTINGS key used to select or review the setting for the parameter that determines the maximum rate of delivery of the tidal volume during mandatory breaths.
PEEP (Positive End Expiratory Pressure)	The pressure at the end of exhalation.
<PEEP/CPAP>	The PATIENT DATA key used to display the calculated PEEP/CPAP pressure in the cmH_2O window. PEEP/CPAP also refers to the PATIENT DATA control knob used to select the PEEP level. See CPAP and PEEP.
<PLATEAU>	The VENTILATOR SETTINGS key used to select and review the value for the inspiratory pause that follows the delivery of a mandatory breath. PLATEAU is also the PATIENT DATA breath-type indicator that lights during an inspiratory pause.
<PLATEAU PRESSURE>	The PATIENT DATA key used to display the measured plateau pressure in the cmH_2O window. It is blank when plateau equals 0.
Pneumatic System	The system, controlled by microprocessor electronics, which regulates the flow of air and oxygen to the patient. See also Proportional Solenoid Valves.
POST (Power-On Self-Test)	A ventilator self-diagnostic test that automatically checks microprocessor electronics whenever the ventilator is turned on and when QUEST and TEST are initiated. POST runs automatically if a system error is detected. See also QUEST and TEST.
Pressure Transducer	A pressure-sensitive electrical device that converts pressure into electrical signal. See Flow Sensor.

Term	Definition
Prompt	Operator instructions that appear in the message window, generally requiring an operator action. See Message.
Proportional Solenoid Valves (PSOLs)	The microprocessor-controlled pneumatic devices that determine the mixture and flow of air and oxygen to the patient. Control of these valves determines the waveform, tidal volume, plateau, peak inspiratory flow, and O_2% of the delivered gas.
QUEST (Quick Extended Self-Test)	The abbreviated form of EST to be performed by the operator at every change of a patient circuit.
Ramp Key	See Descending Ramp Key.
Reset Button	A safety device that "trips" (stops power from reaching the ventilator) if an electrical overload occurs. Reset the ventilator or the compressor (if installed) by pressing the appropriate button. The ventilator reset button is located on the utility panel; the compressor reset button is located on the side of the compressor.
<RESPIRATORY RATE>	The VENTILATOR SETTINGS key used to select or review the setting for the parameter that determines the number of breaths per minute for ventilator-initiated mandatory breaths during CMV and SIMV.
SAFETY VALVE OPEN (SVO)	An emergency condition during which the patient breathes room air, unassisted by the ventilator. This mode is automatically initiated whenever any of the following conditions occurs: both the ventilator's air and oxygen supplies are nonfunctional; POST is running; a system fault is detected; AC voltage to the ventilator is lost. SAFETY VALVE OPEN is also a red alarm summary display indicator.
<SENSITIVITY>	The VENTILATOR SETTINGS key which triggers the pneumatic system to deliver breaths. This setting specifies the pressure drop required to begin a patient-initiated mandatory or to maintain a spontaneous breath. The sensitivity value is entered as a positive number and subtracted from PEEP to calculate the inspiratory threshold. See also Mandatory Breath, Patient-initiated Mandatory Breath, or Spontaneous Breath.
SET RATE bpm	The VENTILATOR SETTINGS window that continuously displays the current, operator-selected setting for respiratory rate. Display applies only to mandatory breaths and is blanked when the CPAP modes is active.
SIGH	The PATIENT DATA breath-type indicator that lights during the sigh breath cycle.
Sigh Breath	A type of mandatory breath with four operator-selected parameters: sigh tidal volume, sigh high pressure limit, sigh events per hour, and multiple sighs per sigh event. A sigh breath can, depending on the tidal volume setting, deliver a larger than normal tidal volume.

Term	Definition
<SIMV> (Synchronized Intermittent Mandatory Ventilation)	The VENTILATOR SETTINGS mode key used to select the ventilation mode in which breaths may be either mandatory or spontaneous. See CMV, CPAP, PIM Phase, and Spontaneous Phase.
Sine Waveform Key	Key used to specify sine waveform.
SPONTANEOUS	The PATIENT DATA breath-type indicator that lights during a spontaneous inspiration.
Spontaneous Phase	The remainder of a SIMV cycle following a patient-initiated mandatory breath.
Spontaneous Breath	One of the breath types the ventilator can deliver. The operator determines a spontaneous breath's O_2%. Patient effort determines a spontaneous breath's tidal volume, flow rate, and waveform. See Mandatory Breath.
Square Waveform Key	The VENTILATOR SETTINGS key used to select the square waveform.
Sterilization	A process that kills microorganisms. Common sterilization techniques include steam autoclaving, exposure to ETO gas, and chemical disinfection.
SVO	See Safety Valve Open.
System Error	A ventilator malfunction that does not jeopardize gas delivery to a patient. POST and ongoing checks detect system errors. See System Fault.
System Fault	A ventilator malfunction that may jeopardize gas delivery to a patient. System faults may be detected during QUEST and TEST; ongoing checks can also detect some system faults, BUV is inhibited by system faults. See System Error and Ventilator Inoperative.
<TIDAL VOLUME>	The VENTILATOR SETTINGS key used to select or review the setting for the parameter that defines the value for the volume of gas, corrected to BTPS, delivered to the patient for all non-sigh mandatory breaths. TIDAL VOLUME also refers to the PATIENT DATA key used to display the current value for tidal volume in the liters window. Tidal Volume also refers to the volume of gas delivered to a patient during a mandatory breath. The actual volume of gas leaving the pneumatic system during a mandatory breath equals the tidal volume or sigh tidal volume setting plus the compliance volume of the patient service system and BTPS correction.
TIDAL VOL liters	The VENTILATOR SETTINGS window that continuously displays the digital value for the current, operator-selected tidal volume setting.
TEST (Total Extended Self-Test)	The thorough version of EST performed by the technician as part of periodic maintenance procedures.

Term	Definition
Transducer	See Flow Sensor and Pressure Transducer.
Utility Panel	The portion of the ventilator where the power switch, reset button, EST button, alarm volume control knob, output signal connector, rating label, and power cord are located.
Ventilator-initiated Mandatory Breath (VIM)	A mandatory breath initiated according to the operator-selected setting for <RESPIRATORY RATE>. See also Operator-initiated Mandatory Breath or Patient-initiated Mandatory Breath.
VENTILATOR INOPERATIVE	The alarm summary indicator that lights whenever a system fault is detected. The safety valve opens and the SAFETY VALVE OPEN display lights. The detection of a system fault means the ventilator is inoperative and the patient is breathing room air, unassisted by the ventilator. See Safety Valve Open and System Fault.
VENTILATOR SETTINGS	Section of the keyboard display panel used by the operator to select ventilator settings.
VENTILATOR STATUS	Section of the keyboard display panel which reports the ventilator's operation condition and alarm status.
Waveform	The ventilator's time-dependent gas flow patten during a mandatory breath. The ventilator produces three operator-selected waveforms: square, descending ramp, and sine. See Square Waveform, Descending Ramp Waveform, and Sine Waveform.
<*> (Asterisk) Key	(Key on keyboard display panel used to reverse through <++> key functions or through automatic sigh parameters.
<•> (Decimal Point) Key	The VENTILATOR SETTINGS key used to select tractional values for ventilator settings.
<++> (Plus-Plus) Key	The VENTILATOR SETTINGS key used to access an option or a special function such as apnea ventilation parameters or clock-calendar reset.
[Square Brackets]	Square brackets are used to signify messages or prompts appearing in the message window on the keyboard display panel. For example, when the ventilator detects apnea, the message [APNEA VENTILATION] is displayed.
<Angle Brackets>	Angle brackets are used when referring to titles of keys on the keyboard display panel. For example, to change the tidal volume, press the <TIDAL VOLUME> key.

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